SCOPE AND OUTCOMES OF A TRAUMA QUALITY IMPROVEMENT PROGRAM AT ROYAL PRINCE ALFRED HOSPITAL, AUSTRALIA 2006-2016

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CONFLICTS OF INTEREST

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AUTHORSHIP CONTRIBUTION STATEMENT

This thesis was written entirely by Michael Dinh. All published studies submitted as part of this thesis (excluding Appendix) were principal authored by Michael Dinh. He had principal roles in every literature review, data coding, statistical analysis and manuscript preparation for studies contained within this thesis. He was the corresponding author for all studies published as part of this thesis except for Chapter 7. Both Doctoral supervisors provided expert advice and assistance for statistical analysis, study designs and manuscript preparation.

STATEMENT OF ORIGINALITY

This is to certify that to the best of my knowledge, the contents of this thesis are my own work and that all assistance received in the preparation of this thesis has been acknowledged. This thesis has not been submitted for any other degree or purposes other than publication in peer-reviewed scientific journals contained herein.

Signature

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LIST OF PUBLICATIONS AND AUTHOR ATTRIBUTION STATEMENT

I was the Chief Investigator and Principal Author, with roles in the study conception, design, literature review, data collection, analysis and manuscript preparation and publication for the following studies that appear in the following chapters of this thesis.

1. Chapter 3 - Dinh MM, Byrne CM, Petchell J, Hill DA. A brief history of emergency and trauma care at Royal Prince Alfred Hospital, Sydney Australia. Accepted Trauma and Emergency Care 2017
2. Chapter 8 - Dinh MM, Bein KJ, Berendsen Russell S, Muscatello D, Ivers R. Age-related trends in injury and injury severity presenting to emergency departments in New South Wales Australia. Accepted Injury August 2016
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5. Chapter 12 - Dinh MM, Bein KJ, Hendrie D, Gabbe B, Byrne CM, Ivers R. Incremental cost-effectiveness of trauma service improvements for road trauma casualties: experience of an Australian major trauma centre. Aust Health Rev. 2015 Sep 14. doi: 10.1071/AH14205.
6. Chapter 13 - Dinh MM[1], Cornwall K, Bein KJ, Gabbe BJ, Tomes BA, Ivers R. Health status and return to work in trauma patients at 3 and

6 months post-discharge: an Australian major trauma centre study. Eur J Trauma Emerg Surg. 2015 Aug 11.

The following papers have been submitted in relevant peer-reviewed scientific journals and are pending outcomes. I was the Chief Investigator and Principal Author for all except Chapter 7 which was co-authored by an Emergency Medicine Fellow I was supervising during 2016.

Chapter 4 - Dinh MM, Roncal S, Ivers R, Gabbe B. What is a trauma patient? Implications for a hospital trauma registry and trauma system evaluation at an Australian Trauma Centre. Submitted to Injury September 2016

Chapter 7 - Oliver M, Dinh MM, Balogh Z, Paschkelwitz R, Curtis K, Rigby O. Trends in trauma procedures performed at Major Trauma Centres in New South Wales Australia. An analysis of State-wide trauma data. Submitted to ANZ Journal of Surgery, awaiting review September 2016

AUTHORSHIP ATTRIBUTION STATEMENT

In addition to the statements above, in cases where I am not the corresponding author of a published item, permission to include the published material has been granted by the corresponding author

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As supervisor for the candidature upon which this thesis is based, I can confirm that the authorship attribution statements above are correct.

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TABLE OF CONTENTS

Legend: # Submission pending peer review outcome, *publication in peer reviewed journal, ^ available online on hospital intranet

ABSTRACT

ABSTRACT

Background

Injury and trauma remain important causes of morbidity and mortality globally. Trauma systems have been established to facilitate optimal management of injured patients, including timely access to specialist trauma centres in those who are severely injured. Trauma quality improvement programs have emerged over the past decade to evaluate and improve quality of care delivered by trauma systems and trauma centres. Despite this, there remains little evidence to demonstrate that these quality improvement programs actually improve patient outcomes or whether they are cost-effective. In 2006, a trauma quality improvement program was initiated at Royal Prince Alfred Hospital, Australia. This consisted primarily of the implementation of trauma team activation and resuscitation protocols, and the evaluation of care through the use of clinical indicators (key performance indicators) and measurement of post discharge health status.

Objectives

This thesis describes a quality improvement program at Royal Prince Alfred Hospital that involved monitoring of all major clinical services involved in the acute care of trauma at this hospital, and evaluates this program with respect to in-patient mortality for severe injury, cost effectiveness and long term outcomes.

Methods

The studies were conducted at Royal Prince Alfred Hospital (RPA) in New South Wales Australia. The thesis is presented in four main sections. The first section (chapters 1 to 4) provides an outline of the thesis and summarises the current literature on trauma quality improvement programs. Preliminary papers describe the historical context of the trauma service at this institution and discuss the conceptual framework for trauma patient data collection. The second section (chapters 5 to 9) provides background information regarding contemporaneous trends in injury presentations to Emergency Departments

and major trauma activity and mortality across NSW. The third section (chapters 10 to 13) details and evaluates the impact of the trauma quality improvement program on long-term major trauma mortality trends at this hospital using time series analysis and its cost effectiveness in a subset of road trauma patients. It also investigates health status outcomes in trauma patients at three and six months after hospital discharge - a project initiated as part of the quality improvement program.

Results

Injury is one of the leading causes of presentations to Emergency Departments across NSW and the critically injured make up around 1% of total injury presentations. Major trauma in-hospital mortality across NSW has remained stable at around 16% between 2003 and 2014. The trauma quality improvement program at RPA was associated with a significant reduction in major trauma mortality from 16% to 10% after 2007. The incremental cost effectiveness was estimated to be $7600 per year of life saved in the subset of road trauma patients. Analyses of health outcomes after discharge revealed increasing injury severity and upper limb injuries were the only predictors of reduced employment status after injury, and lower limb injuries were associated with reduced physical health status compared to those without lower limb injuries at both 3 and 6 months post discharge. Around 37% of patients reported signs of psychological distress and this did not change significantly during the study interval.

Conclusions

This thesis has published important new information regarding the clinical and cost-effectiveness of trauma quality improvement programs. It contains the first published studies evaluating these interventions using formal time series and health economics analysis and one of few reporting the intervention in the context of existing injury and trauma management systems in New South Wales Australia.

PREFACE

PREFACE

In September 2006 when my tenure with the Department of Trauma Services commenced, one of my first tasks was to attend a meeting with the Deputy Director General of Health for a presentation given by my colleague and Co-Director Dr Jeffrey Petchell and Professor Paul Torzillo, Clinical Stream Director of Critical Care Services. The aim of the presentation was to outline the case for Royal Prince Alfred Hospital (RPA) to remain a major trauma hospital. At the time, and unbeknownst to most clinicians at the hospital, the Greater Metropolitan Clinical Taskforce and New South Wales (NSW) Institute of Trauma and Injury Management were in the final stages of revising the NSW State Trauma Plan. One of the options being seriously considered was the closure of all but three much larger and more established trauma services in Sydney – Liverpool, Royal North Shore and Westmead Hospitals. This proposal was based largely around the surgical volume and outcomes hypothesis, as well as the more highly regarded Victorian State Trauma system, which had proven to be a success in improving outcomes for major trauma patients. We were faced with the distinct possibility that RPA would, for the first time in its 125 year history, no longer treat major trauma. Critical Care, Emergency and Surgery clinicians at RPA, and indeed my stewardship of the trauma department therefore owe much to Dr Petchell's timely intervention, convincing decision makers of the need for an inner city trauma centre, in reasonable proximity to the Central Business District, in the largest city in Australia.

The need for service improvements at RPA by that stage was however acute. There was at the time very little by way of resources to support trauma education, formalised processes of care, research or quality improvement at this hospital. Major trauma mortality (Injury Severity Score>15) was hovering between 16 to 20%, for much of the previous decade. With strategic enhancements to the trauma service in 2006, research output trebled, processes were benchmarked and the cost effectiveness of our trauma quality improvement program was, and remains, one of the few in the world to be established. Instead of focusing only on major trauma patients and their needs, we instead focused on the needs of *all* trauma patients. The change was fundamental. Within five years of that fateful presentation to the Department of Health, major trauma mortality at this hospital had fallen by 40% and this hospital would have the lowest risk adjusted in-hospital mortality of all twenty six major trauma centres in Australia.

This is the story of how a small trauma service began to focus on research and quality improvement, and in doing so, came back from the brink to ultimately improve patient outcomes. It is fundamentally a thesis about change – changes in attitude, processes, outcomes that will hopefully add to the growing body of literature on trauma quality improvement and inspire other services, particularly smaller ones in regional and rural Australia to embark on a similar mission.

A mission like this would not be possible without first and foremost the dedication and hard work of my colleagues in the Department of Trauma Services. It would have been difficult under normal circumstances for someone like me, a newly minted and very junior Fellow of The Australasian College for Emergency Medicine (FACEM) to take on this role and even suggest, let alone implement any substantial change. Trauma at the time was still considered a surgical subspecialty. A Co-Director model of trauma leadership involving an Emergency Physician had not been described in Australia and my appointment was suffice to say, truly untested territory at RPA. In Sue Roncal, Elizabeth Leonard, Chris Byrne and Jeff Petchell, I found colleagues who were not only dedicated and passionate about trauma care, but had a willingness to innovate and work with me. In practical terms, minimum dataset collection doubled, trauma assessment forms were standardised, new and existing protocols were drummed into clinical staff week in and week out at education sessions and simulation and decision support tools embraced.

To Sue Roncal in particular, who understood the value of data and willingly doubled her workload for the cause, graciously put up with my almost weekly requests for data, even deferring her retirement in 2014 to see this program of quality improvement through – a special thank you. This thesis is a tribute to your twenty five years of unrelenting service to this grateful hospital. To the trauma Clinical Nurse Consultants and Case Managers Liz Leonard, Kevin Cornwall, Ebon Smith, Jameela Truman and all previous members of staff (Amanda Stack, Karen Creighton, Saartje Berendsen Russell, Kristen Gordon). Thank you for supporting the program of change that we implemented over the past decade, and understanding the need for a data driven approach to policy and quality improvement. To Chris Byrne and Jeff Petchell – it's been an absolute pleasure and honour working with you. Hopefully the "three amigos" will stick around the trauma department for a few more years to come. I would also like to thank Tim Green, Emergency Department Director at Royal Prince Alfred, for his unwavering support, leadership and mentorship throughout my career, first as a Junior Registrar at RPA, to my time as a Senior Staff Specialist. Your support during my Masters at The Harvard School of Public Health was telling, and this compendium of research publications is a return on investment for your support. A true academic Emergency Medicine Unit, a fantasy but a few years ago, is now within our grasp.

To my doctoral supervisors, Professor Rebecca Ivers and Professor Belinda Gabbe; I am indeed fortunate to have two important and pre-eminent trauma and injury researchers in Australia supervise and look over my work during the past four years. I have learnt so much about research methods, statistical modelling and outcomes evaluation. Thank you for your guidance and most of all patience. You have facilitated not just this thesis but the improvement in outcomes reported herein. For that, the trauma service at RPA and the patients we serve thank you. To my colleague Kendall Bein, a rare data analyst who doubles as an Emergency Physician in his spare time: Thank you for cleaning up and coding all those spreadsheets. "Helen of Troy" (a pseudonym for a data spreadsheet coding program) did indeed launch a thousand ships (at least 40 in the past decade anyway).

To my loving, supportive, super organised wife Wynne and my three young children Sam, James and little Wynona. Thank you for putting up with my late nights after work and weekends writing reports, research papers and analysing data, when we should have been playing games, watching TV and spending time together. Wynne, the sacrifice and hard work was as much yours as mine

and I hope, after all these years, and after deferring your own (more lucrative) career ambitions, you'll still have faith in my promise to make it up to you.

And one final word of dedication. In 1972, a young thirty year old Computer Sciences major submitted a doctoral thesis to the Faculty of Engineering at Tokyo University. It focused on process optimisation and statistical control within chemical factories in post-war Japan - an industry where any deviation, even to the second decimal point from standard, had major ramifications. He always wanted to be a medical doctor in Vietnam, but his family couldn't afford to send him to medical school during the American war. He escaped to Japan, studied hard, graduated with first class honours, typed his doctoral thesis in Japanese and English, married a beautiful woman, resettled in Australia, raised two reasonably functional boys (neither of whom will ever come close to being as intelligent), and the rest they say is history. This thesis is for you Dad.

ABBREVIATIONS

AIS – Abbreviated Injury Scale

RPA – Royal Prince Alfred Hospital

ISS – Injury Severity Score

EDDC – Emergency Department Data Collection Registry

CHeReL – Centre for Health Record Linkage

DESTINY – Demand for Emergency Department Services Trends in Years 2010-2014

T1 – New South Wales Ambulance Service Major Trauma transport protocol

SD – Standard Deviation

ICU – Intensive Care Unit

IQR – Interquartile Range

US – United States of America

FTE- Full time equivalent

INAR – Integer valued Autoregressive Poisson model

95%CI – 95% Confidence Interval

NSW – New South Wales

YLL – Years of Life Lost

SF – Short Form

EQ5D – Euro-Qual 5 Dimension

LOS – Length of Stay

SBP – Systolic Blood Pressure

GCS – Glasgow Coma Scale

SNOMED-CT - Standardised Nomenclature for Medical Diagnoses-Clinical Terms

ICD – International Classification of Diseases

GLOSSARY OF TERMS

Injury

Any physical damage to body tissues resulting from blunt or penetrating force

Trauma

A biopsychosocial concept that encompasses the injury itself, together with the biological, psychological, health system and societal response to that injurious event

Trauma patient

Any person sustaining physical injury who requires trauma system assessment and management

Trauma system

An organised approach to the care of injured patients, comprising a network of pre-hospital, hospital and rehabilitation organisations that work under a common framework of defined policies and procedures directed at ensuring the injured patient receives effective and timely health care.

Trauma centre

An acute care hospital that has been designated by an external governance body as being capable of treating trauma patients

Abbreviated Injury Scale

An injury coding system first published in 1974 that grades the severity of injuries on a scale of 1 to 6 from minor to non-survivable respectively. Injuries are classified into head, face, neck, chest, abdomen, vertebral column, upper limb, lower limb (including pelvis) and external (skin and burns) regions.

Injury Severity Score

The Injury Severity Score (ISS) is a measure of the overall severity of injury sustained by a patient. It is calculated by assigning the highest AIS score (most severe individual injury) for each body region and squaring the AIS score for the three most severely injured body regions. These three squared values are summed to obtain the Injury Severity Score. It has been used to model mortality to derive the Trauma Injury Severity Score (TRISS) in combination with the Revised Trauma Score (a composite of initial vital signs), mechanism of injury and patient age. Historically, the definition of severe trauma was an ISS greater than 15, based on an estimated mortality of greater than 10%. Lately, trauma registries have lowered this ISS threshold to 12 and some use 9 to define severe trauma.

Major trauma

A composite outcome comprising severe injury based on an Injury Severity Score and need for Intensive Care Unit admission, urgent operative management or death due to injury.

Under-triage

Number of major trauma patients that were not identified by trauma triage and transport protocols as a proportion of the total number of trauma activations. Higher under-triage correlates with lower sensitivity of a protocol to identify major trauma patients, and results in patients not being managed by the trauma system. Under-triage can lead to delays in definitive care and transport of major trauma patients to non-trauma centres

Over-triage

Number of non-major trauma patients as a proportion of the total number of trauma activations. Over-triage reflects the overall efficiency of a triage protocol, and higher over-triage implies that injured patients are brought unnecessarily to designated trauma centres, assuming that other facilities can adequately manage these patients. Alternatively over-triage of hospital based triage protocols means that hospital trauma teams are being mobilised unnecessarily for patients that could be adequately managed by the Emergency Department clinicians or minor injury clinics.

Trauma team

At major trauma centres, these comprise a group of clinicians including Emergency Department, Intensive Care unit, Anaesthetics and General Surgery Registrars and or Consultants, Radiographers and Emergency Nurses. Teams assemble in the Emergency Department in response to a trauma activation page.

Royal Prince Alfred Hospital

Royal Prince Alfred Hospital is a 900 bed quaternary referral centre and teaching hospital for the University of Sydney. It is located adjacent to the University around 5km to the west of the Central Business District of Sydney in New South Wales Australia. Besides being a Major Trauma centre, it is the referral hospital for Liver and kidney transplantation, Oncology (Chris O'Brien Lifehouse), Mental Health (Marie Bashir Institute), pelvic surgery and exenteration and metabolic and cardiovascular research (Charles Perkins Centre). Other research institutes include the Centenary, Blackburn and Baird Institutes. In 2017 The George Institute for Global Health will relocate to a new building adjacent to the hospital precinct.

Policy

A framework or set of practices that define optimal care within an organisation

Protocol

A series of ordered processes designed to achieve a specific and desired outcome or response

Quality improvement

The process by which quality of care, based on predefined parameters, are implemented, measured and improved over time

Case Management

This is a process by which clinicians review the quality of care given to a patient. Clinical notes are reviewed at the time of tertiary survey and benchmarked against pre-defined audit filters. Any deviations are entered into the trauma registry and discussed at regular weekly trauma unit meetings

Incremental Cost Effectiveness Ratio

Ratio of additional cost associated with an intervention over the benefit gained from the intervention. For example the costs of a quality improvement program include all additional staffing costs and benefit is the number of years of life saved.

In-patient

A patient who stays within a unit or clinical area of the hospital prior to discharge to place of usual residence

Clinical indicator

Performance benchmarks representing desired clinical outcome or event that can be measured through routine case management or abstraction of clinical notes

Severe Injury

Defined anatomically as a patient with an Injury Severity Score greater than 15. Prior to 2010, AIS version 1998 was used to code injuries and calculate ISS (patients presenting in years prior to 1998 had injury codes converted to 1998 version). After 2010, AIS version 2005 was used. Previous years were not converted to the current AIS version except for the cost effectiveness analysis in Chapter 12. In 2012, the state-wide definition of severe injury changed to an ISS of greater than 12, and as a result the paper written in chapter 7 using state-wide data used this newer definition of severe injury.

LIST OF TABLES AND FIGURES

All photos used in this thesis were approved for use by Sydney Local Health District Audio-Visual Services

CHAPTERS 10-13 INTERVENTION AND OUTCOMES

INTRODUCTION

CHAPTER ONE

> "…when you can measure what you are speaking about and express it in numbers you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind: it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of *science*, whatever the matter may be."
>
> William Thomson, Baron Kelvin From Thomson, W. (1891). *Popular Lectures and Addresses, Vol. I*. London: MacMillan. p. 80.

INTRODUCTION AND THESIS STRUCTURE

The objective of this thesis-by-publication was to describe and evaluate a trauma quality improvement program at an Australian major trauma centre with respect to in-hospital mortality for severe injury, cost-effectiveness and post discharge outcomes. Trauma quality improvement programs are specific initiatives designed to improve the quality of care and outcomes of patients cared for in designated trauma centres. They have evolved to become important components of trauma systems of care. The program involved the trauma service as a whole, included all trauma patients, across all domains of acute hospital care (Emergency, Operating Theatre, Intensive Care, ward and post discharge). As this is a thesis by publication, a description, appropriately referenced, of the conceptual framework of data collection, background information regarding trauma care and the NSW trauma system are contained in subsequent chapters, rather than summarised in this introduction, which instead outlines the structure and contents of this thesis.

CONTEXT AND CONCEPTUAL FRAMEWORK

The rationale for this program of research is encapsulated in the literature review contained in chapter 2. This chapter highlights the paucity of evidence and the need for more comprehensive scientific evaluation of trauma quality improvement programs, thereby defining the rationale for this thesis. No analysis of such programs has been published using formal time series analysis or corroborated using cost-effectiveness analysis. The next chapters provide historical background, context and background information to the NSW trauma system, clinical care and trends in trauma mortality and activity over the past decade. Chapter 3 summarises the history of emergency and trauma care at RPA to provide historical background to the current trauma service at this hospital. Chapter 4 provides the conceptual framework to the trauma quality improvement program and begins with the question, "What is a trauma patient?" This was a basic, even esoteric but fundamental question. Being able to define who the core patients were, underpinned everything from the measurement and evaluation of trauma activity and trauma triage through to specific quality improvement programs directed at trauma patients and the measurement of long term post discharge outcomes. It therefore provides a rationale for the shift in operational definition of a trauma patient at RPA from one based on injury severity and in-patient resource utilisation to one focused on service delivery.

Chapters 5 to 8 establishes the context for the quality improvement program within the framework of the current NSW trauma system, and the underlying trends affecting current major trauma care in NSW. Major works on the scope of injury and trauma care in NSW and contemporaneous trends in major trauma mortality across major trauma centres in NSW are presented. Trends in injury and trauma related presentations across NSW Emergency Departments are presented, representing the first such analysis in NSW, providing a measure of the burden of injury in this setting. The paper on major trauma mortality trends in NSW was written to provide the context for the mortality changes that occurred following the quality improvement program at RPA.

INTERVENTION AND OUTCOMES

The quality improvement program is then detailed in chapters 10 and evaluated in Chapters 11 to 13 using in-patient mortality time series analysis, followed by a cost effectiveness analysis of the trauma quality improvement program. The thesis closes by describing post discharge outcomes of trauma patients, undertaken as part of the quality improvement program, and touches on the feasibility of measuring such important patient centred outcomes at the trauma service level. This was an important component of the trauma quality improvement program as it allowed the trauma service to evaluate its care and establish a baseline from which future quality improvement programs may be evaluated. The appendix includes key examples of policies and procedures implemented as part of the trauma quality improvement program, the latest RPA Trauma Annual Report that highlights trends in outcomes and ongoing strategic challenges, health status outcome tools and copies of the six published works as they appear in peer reviewed journals.

SUMMARY OF METHODS USED IN THIS THESIS

The following contains a brief synopsis of the analytical methods used in this thesis. More detailed descriptions of statistical modelling techniques are contained within individual publications.

The quantitative section of this thesis begins with a descriptive analysis of trends in injury presentations to emergency departments using the New South Wales State-wide Emergency Department Data Collection Registry between 2010 and 2014. The purpose of the study was to describe trends in critically injured patients, defined as any patient presenting to an Emergency Department with an injury diagnosis based on Standardised Nomenclature for Medical Diagnoses-Clinical terms SNOMED-CT or International classification of diseases International Classification of Diseases (ICD) code, assigned a triage category one or two (life threatening or potentially life threatening) and transferred from ED to the operating room, intensive care unit or another facility or died. The primary outcome was age specific rates of emergency department presentation. Trends were plotted on line charts and modelled using negative binomial regression.

Further context to the NSW trauma is provided in the following paper, which describes contemporaneous trends in major trauma mortality in NSW between 2009 and 2014. The purpose of this study was to provide the background and baseline in-patient mortality trends across major trauma centres in New South Wales and provide a reference point from which in-patient trends at this hospital can be compared. Major trauma patients were defined as those with an Injury Severity Score greater than 15, consistent with previous studies of major trauma in NSW[1]. All major trauma centres and three regional trauma centres were included in this analysis. The primary outcomes were crude and risk adjusted in-patient mortality, and trends in both were described using Cochrane-Armitage trend tests and Generalised Additive Models respectively.

The next analysis evaluates the impact of the trauma quality improvement project initiated in 2007 on long-term trends in major trauma mortality at Royal Prince Alfred Hospital. All adult major trauma patients (ISS>15) between 1992 and 2012 were identified using the hospital trauma registry. The statistical modelling method used was integer valued Poisson autoregressive model (INAR). These recently described models have been used to model road traffic incidents but have not been used in a clinical or trauma context to date[2]. Like Autoregressive Moving Average (ARIMA) models they can account for serial autocorrelation, which is important to factor underlying trends in mortality, but unlike ARIMA models that rely on the normality of errors assumption, INAR can be used for dispersed count data, which is ideal in the context of random count events such as monthly major trauma death counts, the primary outcome of this study. A variable to represent pre or post intervention year 2006 was used to compare the monthly counts of major trauma deaths after multivariable adjustment.

The cost-effectiveness of the trauma quality improvement project was evaluated in a subset of major trauma patients involved in road trauma between 2001 and 2011. This subgroup was obtained from the original 1992-2012 data described in the previous paragraph. Years of life lost (YLL) per patients were estimated using current Australian Bureau of statistics life tables. As there was an excess in zero counts of years of life lost in those who survived, zero inflated negative binomial regression was used to model YLL adjusting for age and other important covariates, and obtain the adjusted mean YLL associated with either pre and post intervention periods. The cost effectiveness was then expressed as the cost per year of life gained (difference in mean YLL between the two periods) and 2012 Australian dollar values were used with a 5% annual discount rate for costs and outcomes.

The follow up health outcomes study, initiated as part of the trauma quality improvement project was a prospective cohort study conforming with STROBE guidelines. Adult trauma patients aged between 16 and 65 years of age who had undergone trauma team activation in the emergency department and were admitted to the hospital were eligible for the study. Patients with severe brain injury, assault trauma and pre-existing cognitive deficits were excluded. Patients were followed up three and six months post discharge from hospital with telephone calls. Health status using Short Form 12 and EuroQuol 5D and Glasgow Outcomes Scale were used consistent with the framework established by the Victorian State Trauma Outcomes Registry. SF12 values were normalised using Australian based norms. To determine multivariable predictors of these continuous outcomes over time, repeated measures mixed models were used. The driver of the study was to provide evidence and needs analysis for further quality improvement projects related to post discharge outcomes. It also sought to explore the feasibility of routine post discharge follow up of trauma patients.

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2. Quddus MA. Time series count data models: an empirical application to traffic accidents. Accid Anal Prev. 2008 Sep; 40(5):1732-41. doi: 10.1016/j.aap.2008.06.011. Epub 2008 Jul 9.

LITERATURE REVIEW

CHAPTER TWO

SYNOPSIS

This chapter outlines the current state of knowledge regarding trauma systems of care and includes a brief literature review on trauma quality improvement programs. In doing so, it provide a rationale for the subsequent body of research presented in this thesis and its implications for RPA and the NSW trauma system.

TRAUMA QUALITY IMPROVEMENT PROGRAMS: STATE OF THE ART AND LITERATURE REVIEW

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INTRODUCTION

Injury is one of the leading causes of morbidity and mortality around the world[1]. Driven by increased urbanisation and motor vehicle use in the Asia Pacific region, particularly China and India, road trauma has increased from the tenth to the fifth leading cause of death over the past 20 years[1]. In Australia, the road toll has reduced gradually since the 1970s with the introduction of road safety measures and better systems of post-crash trauma care[2,3]. Nevertheless road trauma remains the eighth leading cause of death and injury whether intentional or non-intentional, is still one of the leading causes of death in those less than forty years of age[1]. In addition, there is an increasing burden of injury evident in the older population with its own particular public health and clinical challenges. Severe head injuries from simple falls is increasing and the number of hospital bed days due to falls in those aged 65 years and over has doubled in the last decade[4]. Implementing models of care to manage the injured elderly will likely be the defining problem of modern trauma systems in Australia over the next several decades.

There is substantial evidence in the scientific literature supporting the notion that organised approaches to trauma care are associated with reduced mortality for severely injured patients[5-9]. Such trauma "systems" vary depending on local needs and constraints, but all involve, more or less, an integrated or "regionalised" network of health care services including prehospital, acute hospital and rehabilitation services designed for one purpose - to ensure the right patient gets treated at the right place and the right time. In brief the aims of the system are to identify and triage injured patients, transport them safely from the scene, resuscitate and treat their injuries in a timely and prioritised manner, in an appropriately resourced trauma hospital and ensure optimal functional recovery and return to society. Trauma systems that are more inclusive, with more centres equipped to treat severe injuries have been found to be associated with reduced mortality for severe injury compared to those with fewer trauma centres[10].

Trauma systems, being multi-agency as well as multi-disciplinary, are heavily reliant on support from all levels of government, as the care and prevention of injuries is as much a social and political imperative as it is a public health and clinical one[11]. Trauma care by its nature is expensive[12] and preventing trauma often requires huge investments in infrastructure such as safer roads and highways and enforcement of laws such as mandatory seat belt, drink driving and helmet use. "Mature" trauma systems, those with well-established systems of care and injury prevention are therefore often synonymous with the developed countries of the world[13]. Within mature trauma systems it is unclear which components of the system are most effective in reducing deaths from severe injury. This has ramifications for other developing countries seeking to implement their own systems of care. Liberman et al[14] analysing data from Quebec Canada, found that prehospital notification, triage protocols and the presence of quality improvement programs were associated with the greatest reductions in odds of mortality at trauma centres[14].

Trauma quality improvement programs have gained interest over the past decade as a means of describing and benchmarking trauma outcomes across the trauma system[15-17]. The framework for these consist of evidence based and peer reviewed key performance indicators or clinical indicators (or audit filters), by which the quality of care at various stages of the patient journey may be measured. A Cochrane review of quality improvement audit filters for trauma published in 2009 reviewed 45 articles and found no pre and post intervention or time series studies of sufficient quality to warrant inclusion and concluded that more needed to be done to research this important area[18]. The objective of this literature review was therefore to describe the current state of scientific evidence in relation to trauma quality improvement programs published in peer review biomedical journals.

METHODS

A search was conducted in July 2016 of MEDLINE, PUBMED AND CINAHL databases for English language full text articles from 2000 to 2016 search terms “trauma centre” (or “center”) and “quality improvement” with abstracts manually reviewed by the author specifically for intervention studies measuring in-hospital outcomes at individual adult trauma centres. Ecological comparisons between trauma centres, reviews and simple descriptive series were excluded.

RESULTS

Results of the search are summarised in Figure one.

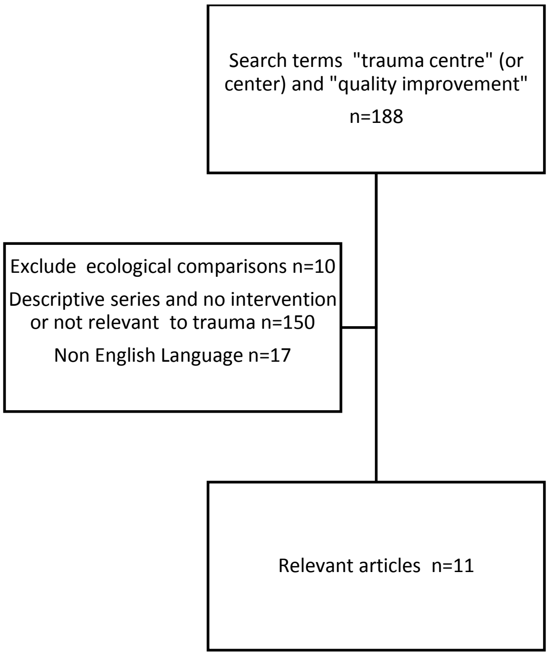

Figure 1 - Search and limit criteria for trauma quality improvement program literature search July 2016

There were 188 abstracts reviewed of which there were 11 relevant articles. These are summarised in Table one. A common theme in many of these trauma quality improvement papers is the evaluation of trauma triage and trauma team activation and massive transfusion protocols. Sarkar et al[20] for instance described a program of trauma team activation and massive transfusion protocol implementation and found a 12% absolute reduction in major trauma (ISS>24) mortality. Most studies have evaluation time frames ranging between

4 and 6 years with the notable exception of Sovik[21] who evaluated mortality after severe head injury over ten years with a program of trauma team activation protocols. All studies used either logistic regression or observed to expected ratios pre and post intervention to evaluate the impact of the trauma quality improvement program.

DISCUSSION

In contrast to trauma systems, there are few studies systematically evaluating *trauma quality improvement programs* over the past two decades. Most of the studies have limitations inherent to short pre-post designs, using univariable and multivariable analyses. They did not account for serial correlation and longer term and underlying trends in outcomes and the factors influencing them. This is particularly important in the context of falling road trauma and road deaths in developed countries. The road toll in Australia has been falling steadily since the 1970s, with the lowest road toll recorded in 2014[2]. Therefore any pre and post study design investigating major trauma mortality is likely to be confounded to some degree by this factor. Analysis of short term data is also likely to be influenced by random short term fluctuations in mortality trends. This was evident in Curtis et al who analysed data from New South Wales and found a statistically significant reduction in major trauma mortality from 15% to 12.7% between 2003 and 2007[30]. Presenting limited data such as these may have misinformed policy makers and government about the effectiveness of the trauma system in NSW. Indeed further analyses published in this thesis of data from 2009 to 2014 showed mortality increasing again to 16% meaning that the long term trend in overall major trauma mortality in NSW has not changed substantially in the past decade. In the only other formal time series analysis relating to trauma systems, published in 2000, Nathens et al[31] found that after adjusting for secular trends in road safety and other underlying trends, mortality benefits of regionalisation and trauma centre verification took around ten years to become apparent.

SUMMARY OF GAPS IN RESEARCH

- Most studies of trauma quality improvement programs used pre post designs with univariable comparisons over a five to seven years
- No systematic analyses of trauma quality improvement programs in the Australian context to date
- No previous studies using multivariable time series analyses or cost effectiveness analysis
- No studies of the effectiveness of trauma quality improvement programs in relatively small designated trauma centres

IMPLICATIONS FOR RPA TRAUMA SERVICE AND NSW TRAUMA SYSTEM

It was in the context of these gaps in knowledge that the trauma service at Royal Prince Alfred Hospital undertook to evaluate a trauma quality improvement program undertaken using formal time series analysis over a twenty one year period. The hypothesis of this program of research was that major trauma mortality was reduced by the trauma quality improvement program. To implement a quality improvement program such as this required the trauma department to redefine trauma patients and what indeed defined optimal care in these patients. Prior to this, case management reviews and key performance indicators focused only "major trauma" – those with a pre-specified injury severity score. These patients made up less than 20% of the total trauma load, and less than one percent of all injuries presenting to the Emergency Department. Afterwards, all patients requiring trauma team activation in the Emergency Department were case managed and became part of mandatory reporting requirements. Key performance indicators were expanded and included components of the newly established triage protocol, massive transfusion and Code Crimson protocols, access to imaging and clinical documentation. Care for every trauma patient was measured against these benchmarks. The hospital trauma triage protocol remains the only such published protocol in Australia to meet American College of Surgeons benchmarks for under and over-triage. It is included in the Appendix for reference only and has been cited by external authors thirty three times since 2010. The long term time series analysis with risk adjustment was also unique and has been cited four times since 2013. A parallel MEDLINE search of terms “trauma centre” and “time series” revealed no relevant citations other than this report. With the help of a health economist, we took trauma service evaluation a step further and described the cost effectiveness of our quality improvement program, the only one in Australia to comprehensively do so. We found using road trauma as an example, that the incremental cost effectiveness of trauma system enhancements and quality improvement program was around $7500 per year of life saved. Finally this new conceptual framework for trauma allowed the tentative introduction of trauma follow up care at this hospital. The principal inclusion criterion for the evaluation study was a patient who underwent trauma team activation upon presentation to the hospital. Thus we were able to start the journey towards post discharge outcomes measurement using the same health status measures used by the Victorian State Trauma Outcomes Registry.

Whilst these are all studies based around the experience of one small inner city trauma centre (except for state-wide data analyses), the results have implications for other trauma services and the NSW trauma system in general. Evaluation of the major trauma Ambulance transport protocol (T1) across NSW requires at the very least that all major trauma services (and regional trauma services) collect and submit outcomes data for the trauma patients they treat, not just the most severely injured ones.

LIMITATIONS

This was a brief literature review conducted by a single investigator to establish the state of current evidence. A formal meta-analysis was not performed given the small number of articles found and the broad range of interventions and outcomes described.

CONCLUSION

Although trauma quality improvement programs have been implemented in many trauma centres, few have evaluated these programs over the long term using systematic time series or cost effectiveness analyses. Further research is required to establish the effectiveness of trauma quality improvement programs before they can be recommended across mature trauma systems.

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TABLE

Reference Number	**First Author**	**Years**	**Setting**	**Inclusion criteria**	**Sample size**	**Statistical methods**	**Intervention**	**Main reported outcome**

19	Perkins et al	2007-2011	United Kingdom	Unstable pelvic trauma	N=185	Logistic regression pre and post	MTP protocol Decision algorithm Pelvic orthopaedic surgeons	OR 0.64 (95% confidence interval (CI) 0.44 to 0.93), p = 0.02)
20	Sarkar	2004-2008	United States	ISS>24	N=1006	Observed to expected ratio (TRISS) pre and post	Trauma activation protocol MTP Pelvic trauma Cervical spine clearance CT imaging time	Mortality ISS>24 reduced from 30% to 18%
21	Sovik	2001-2011	Norway	Trauma patient with severe head injury	N=1251	Cumulative risk adjusted (TRISS) mortality chart	Trauma activation Trauma team training	Improved 30 day survival for ISS >25 from 55% to 70%
22	Kesinger	2010-2012	Colombia	Not reported	N=108	Logistic regression pre and post	Trauma team activation and standard ED resuscitation protocols	Reduced in-patient mortality (OR 0.25, 95%CI 0.07,0.84)
23	Dinh	1992-2012	Australia	ISS>15	N=3856	Time series analysis	Trauma team activation, massive transfusion protocols	In-patient mortality 16% to 10%
24	O'Reilly	2006-2010	United Kingdom	Shocked patients	N=127	Chi squared test for trend	Peer reviewed Morbidity and mortality	Trend test for reduction in mortality p=0.026
25	Laing	2012-2013	South Africa	Penetrating abdominal trauma	N=238	Descriptive before and after	Laparoscopy and trauma registry and standard trauma protocols Weekly morbidity and mortality meetings	Reduction in failed non operative management from 20% to 1%
26	Min	2006-2009	United States	Trauma patients age 65 yrs and over	N=147	Before and after chart audit with logistic	Geriatric trauma consultation service	Improved quality of care measured on audit filters

						regression		
27	Joseph	2011-2013	United States	Non operative brain injury	N=796	Before and after study univariate comparison	Acute brain injury protocol	Reduced repeat CT imaging 91% to 72%
28	Machardo-Aranda	2004-2013	United States	Major trauma ISS>15		Before and after study univariate comparison	VTE prophylaxis protocol	Reduced VTE reduced from 6.2% to 2.6%
29	DiRusso	1994-1998	United States	All trauma patients	N=2774	Before and after study univariate comparison	ACS verification	Mortality reduced from 7.4% to 5.4%

Table one (above) Relevant articles of trauma quality improvement intervention studies found on literature review

HISTORICAL CONTEXT AND CONCEPTUAL FRAMEWORK

SYNOPSIS

The purpose of this section is to provide the historical context of trauma services at Royal Prince Alfred Hospital, as it relates to Emergency Medicine and Trauma care. In doing so the chapter provides a starting point from which further enhancements to the trauma service can be described in later chapters. The second paper in this section provides the conceptual framework which underpinned the quality improvement activities from 2006 onwards. It explains the rationale for the changes to the trauma quality improvement framework. Prior to 2006, quality indicators and full clinical datasets were only reported on major trauma patients with an Injury Severity Score greater than fifteen. Thereafter, clinical data and quality indicators on all patients who were assessed by the trauma team in the emergency department were entered into the trauma registry. This represents a conceptual shift from an injury severity based definition of trauma to a purely operational one.

The following section is a reprint of two submissions currently under review

1. Dinh MM, Byrne CM, Petchell J, Hill DA. A brief history of emergency and trauma care at Royal Prince Alfred Hospital, Sydney Australia. Submitted, Accepted Trauma and Emergency Care, 2017
2. Dinh MM, Roncal S, Ivers R, Curtis K, Gabbe B. What is a trauma patient? Implications for a hospital trauma registry and trauma system evaluation at an Australian Trauma Centre. Submitted to Emergency Medicine Journal March 2017

CHAPTER THREE

A BRIEF HISTORY OF EMERGENCY AND TRAUMA CARE AT ROYAL PRINCE ALFRED HOSPITAL, SYDNEY AUSTRALIA

Although the pioneering role of Royal Prince Alfred Hospital (RPA) in the story of Australian health care is well known, the important role of emergency and trauma care remains unfortunately less well described[1]. One of the first university teaching hospitals established in Australia, RPA indeed had its very origins in emergency and trauma care. During a visit to Sydney northern beaches suburb of Clontarf in 1868, Prince Alfred, second son of Queen Victoria, was shot in the back by a would-be assassin at close range. The bullet was surgically removed from his posterior vertebral column by HMS naval surgeons and he recovered thanks to the care of nurses trained directly under Florence Nightingale (The gold probe used to locate the bullet is now on display in the hospital). The people of Sydney, in gratitude and perhaps out of collective relief, petitioned for a fund to construct a memorial hospital in Prince Alfred's honour. Land for the hospital was granted by the Senate of The University of Sydney seeking to establish a teaching hospital for its new medical school. After some delay due to funding constraints, the hospital was finally opened on September 25th 1882 with 146 beds (True to form, the Victorians had opened The Alfred Hospital eleven years earlier to commemorate the same event).

The twin Victoria and Albert Pavilions were opened on both sides of the original building in 1904 under the direction of Sir Thomas Anderson Stuart then Dean of The Faculty of Medicine and Dr Charles Blackburn[2]. In contrast to the nearby Sydney Infirmary at the time, these pavilions housed wards designed using Nightingale's state of the art principles of nursing and hygiene. Dr Robert Scot Skirving was the first appointed clinical superintendent under Anderson Stuart. As an honorary surgeon and physician (a founding member of both Royal Australian Colleges), an accomplished university lecturer, researcher and administrator, he can perhaps be considered, if only in spirit, a true Emergency Physician.

True Emergency Physicians would not exist for at least another century. During the early days and most of the 20th Century, “Casualty” was a small rudimentary triage area located just to the left in the main corridor as one entered the main entrance. In the late 1880s, trauma patients arrived privately or on a hospital owned ambulance cart drawn by two horses named “Prince” and “Paddy”. They were received by a triage nurse who treated wounds and “streamed” them to the most appropriate in-patient ward. One of these was ward A3, Albert Pavilion, the adult male surgical ward, which had a separate enclosed observation area called “A3 Obs”. Through a small hole in the door, clinicians could observe the “obstreperous and cerebrally irritated, without disturbing them”[3]. This was later described with fondness in the 1930s in scenes not too dissimilar to those in today’s Emergency Department. (See Box)

Ophthalmology was the only surgical subspecialty at the time but others commenced soon after, with gynaecology (1884), ear nose and throat (1898), orthopaedics (1920) and urology (1926). The first orthopaedic appointment was L.G Teece, Director of Medical Gymnastics and Senior Honorary Orthopaedic Surgeon in 1920[4]. The 1930s saw a rapid rise in the use of automobile transportation with a resultant increase in road trauma. The chairman of the hospital during the 1940s and 50s Sir Herbert H Schlink, an eminent gynaecologist foresaw the need for a separate Rehabilitation Unit and Emergency and Accident precinct with 100 dedicated beds and heliport. In his monogram *The Hospital Problem of the Metropolitan and Suburban Area of Sydney* (1940)[5], he postulated that trauma admissions were choking elective surgical and medical beds and advocated for separate streams of care[5]. These plans were shelved in the 1960s and his fears were to have their modern realisation in hospital overcrowding and Emergency Department “access block”. In 1961, with the road toll in Australia soon to peak, the surgical superintendent and orthopaedic surgeon Dr Harry Tyer, changed the long running practice of admitting trauma patients under a general surgical “bed card”. Instead registrars and house officers were instructed to assess and resuscitate the patient and admit the patient to the most appropriate surgical subspecialty, with other units consulting as deemed appropriate[6]. This practice would be enshrined in later years as the Emergency Department admission policy.

The 1980s were marked by State-wide health service and hospital reforms. A trauma system was proposed for NSW in 1988, and launched by Director General of Health Dr Bernie Amos and Professor David A Hill in 1991. Professor Hill, a vascular and trauma surgeon and Dr Richard West, a general surgeon, can be considered the founders of modern trauma services at RPA, helping establish one of the first trauma registries in Australia in 1991 (second only to Westmead Hospital) together with a young trauma data manager, Ms Susan Roncal. Professor Hill modernised trauma education at teaching hospitals by introducing the Structured, Clinical, Objective Referenced, Problem-based, Integrated and Organized (SCORPIO) approach, a format still used today for medical student teaching[6,7]. The trauma registry is particularly impressive with over 60,000 injury cases to date making it one of the largest and most complete longitudinal collections of trauma cases at an Australian hospital.

Emergency Medicine only emerged as a recognised medical specialty in relatively recent times. But the need for specialised critical care and resuscitation physicians within the health system had by that stage become acute. There was an emerging body of scientific evidence regarding the benefits of organised trauma systems, resuscitation and cardiology, and trained and dedicated medical professionals were required to lead this new field of endeavour. The first medical director of the Emergency Department was Dr Graham Yule, an Anaesthetist who was appointed in 1976[7]. Dr Yule transformed what was once a disorganised “Cas” to a full medical department within the hospital, developing and establishing its initial skillsets and core competencies. He went on to play important roles in the founding of both the Society for Emergency Medicine and the Australasian College for Emergency Medicine and was it’s first Honorary Secretary. His mission was fulfilled when Emergency Medicine was subsequently recognised as a principal medical specialty in 1991[8]. Dr Kenneth Abraham was the next director from 1985 to 1994, followed briefly by Dr Sally McCarthy, who went on over a decade later to become President of College. The Emergency Department in those times was located on the ground floor of A Block with Ambulances entering from Johns Hopkins Drive (During World War Two, a unit of the Johns Hopkins University Hospital was stationed in A Block to treat wounded American service personnel). There was one resuscitation bed and two acute beds with an adjacent operating theatre room convenient for simultaneous trauma resuscitation and operative management, but eventually used simply to manage overflow patients. There were few job opportunities and constant struggles for recognition and respect. It was here that the trailblazers toiled and laid the foundations for generations of successful Emergency Physicians at this hospital.

In 1995, as a result of the relocation of the Royal Alexandra Hospital for Children campus at Camperdown to become The Children's Hospital at Westmead, the Emergency Department became a combined adult and paediatric unit. Soon after, it found a new home in its current location within Albert Pavilion backing directly onto Missenden Road. Under the leadership of Dr Janet Talbot-Stern and the indefatigable Nurse Manager Ms Gaye Hudson, undergraduate and postgraduate Emergency Medicine and Nursing programs were consolidated. The adjacent Kater ward (named after Henry Edward Kater, a pastoralist and chairman of the hospital from 1920-1924) was converted into the Winifred Hayett (a much loved volunteer of the hospital) ED tutorial room, simulation lab and staff offices, providing a training springboard for Emergency Medicine primary and fellowship exam candidates and Emergency Nurses for over two decades. The northern balcony of this wing would provide welcome respite for meal breaks, a few staff barbeques and quiet reflection, away from the hustle and bustle down the corridor.

The new millennium was characterised by a rapid and seemingly inexplicable rise in Emergency Department presentations at RPA from around 45,000 presentations to over 75,000 presentations per annum within ten years, driven largely by population growth, access to health care and the ageing population in general. Predictably this led to hospital and Emergency Department overcrowding on unprecedented levels. The department was (and still is) relatively small by any standard, with only three resuscitation bays and twenty four adult beds. Patient trolleys would regularly line up double-file down the central corridor of the department. In response to these challenges, in 2004 the ED Director Dr Tim Green and Nurse Managers Ms Judith Dixon and later Mr Terence Johnson undertook the ambitious task of modernising processes and models of care within the Emergency Department. These included the implementation of mental health Nurse Practitioner models of care, the establishment of the Emergency Medicine Unit (EMU) and measures to improve patient flow. Of these, clinical redesign innovations such as the formalisation of the in-patient team admission policy, team based care and senior early assessment models were to prove a success with dramatically improved patient flow being associated with improved in-patient mortality[9]. During this period, Emergency Medicine training flourished under the stewardship of Dr Jon Hayman, research and audit activity proliferated and RPA evolved to become an important tertiary training post amongst Emergency Medicine trainees in NSW.

With increasing specialisation and the growing expertise of emergency clinicians, there was also a growing recognition that trauma care was no longer the sole realm of general surgery. Indeed the baton of trauma triage, assessment, resuscitation and training had by this time largely passed onto Emergency Medicine and Nursing. A Clinical Nurse Consultant model of care was adopted in 2004 with the appointment of Ms Elizabeth Leonard, a senior Emergency Nurse. In 2006, a newly minted FACEM, fresh from an overseas trauma fellowship was appointed Co-Director of Trauma Services together with Dr Chris Byrne (Colorectal Surgeon) and Dr Jeffrey Petchell (Orthopaedic Surgeon). This represented a model of trauma leadership which was innovative at the time and unique in the southern hemisphere. It heralded a decade of data driven policy evaluation, modernisation and clinical innovation. With engagement and systems-based approach to quality improvement, mortality for major trauma at this hospital almost halved within five years[10]. Trauma nursing was expanded to include a full time case manager and District Trauma Liaison roles. The role of Interventional Radiology increased dramatically to include the non-operative management of most solid abdominal organ and pelvic trauma. The Professor Geoffrey White Hybrid Operating Theatre was opened in 2013, increasing the capabilities of simultaneous surgical and interventional radiological procedures in unstable trauma patients. The Institute for Academic Surgery commissioned in 2016, with its state of the art simulation labs, will continue the tradition of excellence in surgical and critical care education in collaboration with The University of Sydney.

In many respects the stories of emergency and trauma care parallel those in many Australian hospitals. And like many emergency departments, there are ongoing challenges with capacity, workforce and hospital bed shortages. However it is almost impossible to fully appreciate the story here at RPA without understanding its long history. For some perspective, one need only stroll past the front entrance on Missenden Road to see the mix of old and new. Original Victorian-age pavilions and stained glass windows flanked on all sides by modern world-class research and treatment centres. A living memorial to the goals of service and dedicated clinical care conjugated with passionate academic curiosity. And therein lies what I think is at the heart of all good emergency patient care: Practice and research of evidence based emergency medicine anchored by solid traditions and practices which form the bedrock of our clinical craft. For it can be said that although the former stands the test of peer review, the latter also stands the test of time. It was the great scientist Sir Isaac Newton who observed, “If I have seen further, it is by standing on the shoulders of giants”. Such truisms echo down the long hallways of this hospital.

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BOX LEGEND

"A3 Observation Ward" (Author unknown) Excerpt from RPA nursing periodical "Philomena" circa 1930[3]. *The eloquent colloquialism of the day for Emergency Department

Life was mostly froth and beer
In A3 Obs.
Hourly pulses – things that cheer (?)
In A3 Obs.
You will hear a wild man yell
What he'll say you can't quite tell,
Mostly saying—"Go to ----*" well*
Not A3 Obs.
Fractured skulls and fractured minds
In A3 Obs.
Anything that Cas can find*
Goes to A3 Obs.
Its full of men so curt
Whose language is so very pert
Who run about in---*"That pink shirt"*
Out of A3 Obs.

Figure 1 – (circa 1919) The Albert Pavilion Royal Prince Alfred Hospital. Photograph taken from the corner of Missenden Road and "Tin Alley", later Johns Hopkins Drive (with permission RPA Museum)

Figure 2 (below) - The Albert Pavilion 2016 (with permission, RPA Audiovisual services)

CHAPTER FOUR

WHAT IS A TRAUMA PATIENT? IMPLICATIONS FOR A HOSPITAL TRAUMA REGISTRY AND TRAUMA QUALITY OF CARE EVALUATION AT AN AUSTRALIAN MAJOR TRAUMA CENTRE

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ABSTRACT

Background – Controversy exists with respect to the definition of “major trauma” and the optimal method of identifying and measuring trauma activity at major trauma centres. The use of trauma team activation within trauma centres as a measure of activity has not been reported in a long term study.

Objectives – To describe the pattern in trauma team activations at this trauma centre and demonstrate the impact of trauma system changes over the past decade on volume of trauma activation and major trauma, including the implementation of a revised State-wide trauma plan in early 2010.

Methods – This was a retrospective study using trauma registry data at a single Major Trauma Centre in Australia. All trauma team activations recorded in the trauma registry between June 2006 and July 2016 were included. The outcome of interest was the monthly count of trauma team activations, defined as either trauma consult or full trauma team activations occurring within the Emergency Department, and monthly counts of major trauma, defined as an Injury Severity Score >12 or requiring urgent operative intervention or admission to the Intensive Care Unit following trauma.

Results - Median monthly counts of trauma consults increased from 36 (IQR 17-48) to 72 (IQR 65-81) activations during February to June 2010, and remained elevated after this period (58 IQR 53-64) (P<0.001). Full trauma calls increased from 36 (IQR 31-53) to 41 IQR (41-50) during February to June 2010 and reduced after this period 17 (IQR13-22) (p<0.001). Monthly counts of major trauma increased from 15 (IQR12-18) to 27 (IQR 24-31) during February to June 2010 and 18 (IQR 16-22) after the period of February to June 2010 (P<0.001).

Conclusions – The use of trauma team activation as a measure of trauma activity has facilitated the evaluation of trauma system changes affecting this institution over the past decade. Modelling of trauma system changes and its impact on trauma activity at designated trauma centres needs to account for changes in major and non-major trauma presentations.

KEYWORDS

Trauma system, activation

INTRODUCTION

Although the terms "trauma" and "severe injury" are often used synonymously[1], there is little consensus in the scientific literature about what defines severe injury or major trauma, or indeed what actually constitutes a "trauma" patient[2]. As a result, there are a variety of definitions and inclusion criteria for trauma registries around the world. A 2015 international survey of trauma registries by O'Reilly et al[3] demonstrated eight different individual inclusion criteria for trauma registries with substantial variation in the permutations of criteria used. In addition, Injury Severity Score[4] (ISS) thresholds for major trauma vary between 9, 12 and 15[5], exclusion of some injuries[3] (namely isolated neck of femur fractures), but inclusion of many other pathologies unique to the elderly, with little clinical justification for use of one criteria over the other.

Variations in trauma registry inclusion criteria, in particular limiting data collection to major trauma patients, creates potential limitations with respect to injury surveillance and monitoring overall trauma centre performance and the impact of trauma system changes on resourcing and funding models. Firstly major trauma has been shown to make up only a small proportion of overall trauma centre clinical activity. Data from the Queensland Trauma Registry in Australia demonstrates that “minor” trauma patients comprise up to 90% of injury workload within hospitals[6]. Secondly, important components of the trauma system such as trauma triage, trauma resuscitation in the Emergency Department and quality improvement initiatives would be difficult to audit and monitor with data from major trauma patients alone. This is important given that studies of preventable trauma deaths and errors in trauma resuscitation consistently demonstrate the majority of clinical issues arise during the Emergency Department phase of management[7].

A possible alternative trauma registry inclusion criteria is one based around “trauma system” (pre-hospital and or hospital trauma response) activation, particularly if such triage algorithms were consistently applied across a trauma system– in this respect a trauma patient can be regarded as anyone who is identified and managed by the “trauma system”. For example a patient involved in road trauma transported by ambulance to a designated trauma centre on a trauma “code” or “protocol” would be prospectively identified by the receiving trauma service and case-managed by trained trauma nurses and data managers, regardless of injury severity or disposition from the Emergency Department. This approach to data collection has underpinned all recent quality improvement initiatives and has facilitated the evaluation of local triage protocols at this study site[8-10]. Prior to 2006, routine reporting of quality indicators was limited only to those with an Injury Severity Score >15. Thereafter, quality indicators were assessed and recorded for all trauma team activation cases regardless of injury severity. Besides facilitating quality improvement initiatives, this approach also enabled the monitoring of trauma centre activity and the impact of trauma system changes. In 2010, the New South Wales State-wide Trauma Plan was revised with an updated ambulance major trauma triage protocol being implemented, temporary redirection of trauma patients to this study site from another nearby trauma centre and establishment of trauma referral networks for rural and regional hospitals in New South Wales[10]. To our knowledge the impact of these changes on trauma volume and activity have not been evaluated, and no other hospital based trauma registry in this state has reported the use of this definition of trauma patients in a long term study. The objective of the present study was to describe the trend in trauma activations at this trauma centre over the past decade and demonstrate its use this as a measure of trauma centre activity rather than measures based on injury severity alone.

MATERIALS AND METHODS

Design - Retrospective analysis of a single hospital based trauma registry data

Setting - Royal Prince Alfred Hospital is a Major Trauma Centre situated in Inner City Sydney Australia. The hospital treats around 270 major trauma cases a year and over 3000 minor trauma cases. The trauma registry at Royal Prince Alfred Hospital was established in 1991 and has clinical and hospital outcomes data collected by a trauma data manager and trained trauma nurses on all major trauma patients defined as those with an ISS>15 together with an abbreviated dataset on those with an ISS<15. In 2006, the Department of Trauma Services at Royal Prince Alfred extended the inclusion criteria for full dataset collection to include any patient who met pre-hospital trauma protocol criteria or trauma team activation response in the Emergency Department, regardless of admission or discharge.

Patient population - All hospital trauma team activations recorded in the trauma registry between June 2006 and June 2016 (current at time of analysis) were included. Duplicate trauma activations occurring on the same patient on the same day were removed from the dataset.

Data definitions - A trauma team activation response at this hospital was activated either through ambulance notification or patient presentation, meeting criteria specified by the New South Wales (NSW) Ambulance Service major trauma (T1) triage protocol or hospital trauma team activation protocol[8]. The hospital protocol, which is similar to American College of Surgeons Committee on Trauma criteria for trauma triage, has been previously validated against current American College of Surgeons benchmarks for undertriage and overtriage of major trauma patients presenting to this hospital[8]. The activation protocol was two tiered, meaning that patients who had normal vital signs at the scene, and met pre-specified criteria for mechanism of injury (such as fall>3m, pedestrian>20km/hr or motor vehicle crash >60km/hr) received an abbreviated trauma response (Trauma Consult) whilst those with abnormal vital signs or evidence of severe injury received a Full Trauma Team activation.

Other variables abstracted from the data registry for the purpose of this analysis included age, injury severity score, intensive care unit (ICU) admission, and hospital length of stay and hospital outcome. Major trauma was defined by a composite outcome of ISS>12 or admission to ICU or in-hospital death or need for urgent operations. These were defined as the transfer of a patient from the Emergency Department directly to the Operating Room or Angiography Suite. Prehospital arrivals included those cases brought in by NSW Ambulance Service or retrieval transport services. Key time periods examined include calendar October 2006 when the hospital based trauma team activation criteria were formalised and implemented, January 2008 when the trauma team activation protocol formally became a two tiered system, (prior to this trauma consults were activated on an informal basis but after 2008, all patients meeting only mechanism of injury criteria were activated as trauma consults) and

February to June 2010 when a revised NSW State Trauma Plan[11] was initiated, which included a new ambulance major trauma triage protocol across NSW which specified which patients were to be transported directly to the nearest major trauma centre, and temporary diversion of trauma patients to Royal Prince Alfred Hospital from another trauma centre in inner Sydney for five months.

Data Management – All trauma data was entered into a secure hospital based trauma registry from 1992-2009 and a secure online state-wide trauma registry after 2009. The registry was only accessible to trauma data managers and nurse through the local Health Information Environment Citrix network. Data entry was performed by a single AIS coding trained data manager. Quality and hospital outcome measures were entered into the registry by Clinical Nurse Consultants and Trauma Case Managers. Data was externally audited by the NSW Institute of Trauma and Injury Management on a quarterly basis. (See Appendix for screenshots and data flows).

Primary Outcome - The outcome of interest was the monthly count of trauma team activations, defined as either trauma consult or full trauma team activations occurring within the Emergency Department, and monthly counts of major trauma.

Statistical analyses - Descriptive statistics were used to present baseline characteristics of trauma team activations and monthly counts were plotted on a time series chart. Kruskall-Wallis tests were used to compare median monthly trauma activations pre, during and post implementation of the revised NSW major trauma triage protocol in February to June 2010.

Ethics - Access to the trauma registry was approved by the Sydney Local Health District (RPAH zone) Research Ethics Committee

RESULTS

Patient population

A total of 9876 hospital trauma activations were analysed from January 2006 to June 2016. The mean (SD) age was 40.5 (20.0) years and 9.4% were 65 years or over, and males comprised 69.9% of the presentations. There were 3644 (36.9%) full trauma team activations with the remainder (63.1%) being trauma consults. Cases were brought in by ambulance or retrieval services 88.6% of the time and 16.6% of the patient population had an ISS>15. Table one compares outcomes of full trauma team and trauma consult activations. All indicators of severe injury were higher in the full trauma team group (Table one). Of note 12.8% and 85.2% of patients in the trauma consult group who had major trauma outcome or transported to hospital by pre-hospital services respectively.

Trauma Outcomes	**Full trauma team N=3644**	**Trauma Consult N=6194**
Died (%)	176 (4.8)	38 (0.6)
ICU (%)	906 (24.9)	246 (4.0)
Urgent Operation	395 (10.8)	102 (1.6)
ISS >15 (%)	1128 (31.0)	515 (8.3)
ISS > 12 (%)	1207 (33.1)	661 (10.6)
Length of stay 3 days or more	1722 (47.3)	1568 (25.3)
Discharge from Emergency Department	1253 (34.4)	3357 (54.2)
Major trauma (%)	1445 (39.7)	796 (12.8)
Pre-hospital arrival (%)	3435 (94.3)	5310 (85.2)

Table 1 – Trauma outcome characteristics of full trauma team and trauma consult activations from 2006 to 2016 ICU=Intensive Care Admission, ISS=Injury Severity Score, Major trauma = Urgent operation or ICU admission or ISS >12. All p values for comparisons <0.001

Trends

Figure 1 demonstrates the trend in trauma consults and full trauma team activations together with major traumas between 2006 and 2016. The period following October 2006 was associated with a rapid increase in trauma team activations and an increase in Trauma Consult activations after January 2008. The period around February to July 2010 was associated with a spike in activity in both trauma activations and major traumas. Median monthly counts of trauma consults increased from 36 (Interquartile Range IQR 17-48) prior to this period to 72 (IQR 65-81) activations and remained elevated after this period (58 IQR 53-64) (P<0.001). Full trauma calls increased from 36 (IQR 31-53) to 41 IQR 41-50) during February to June 2010 and reduced after this period 17 (IQR13-22) (p<0.001). Monthly counts of major trauma increased to 27 (IQR 24-31) from 15 (IQR12-18) prior to and 18 (IQR 16-22) after the period of February to June 2010.

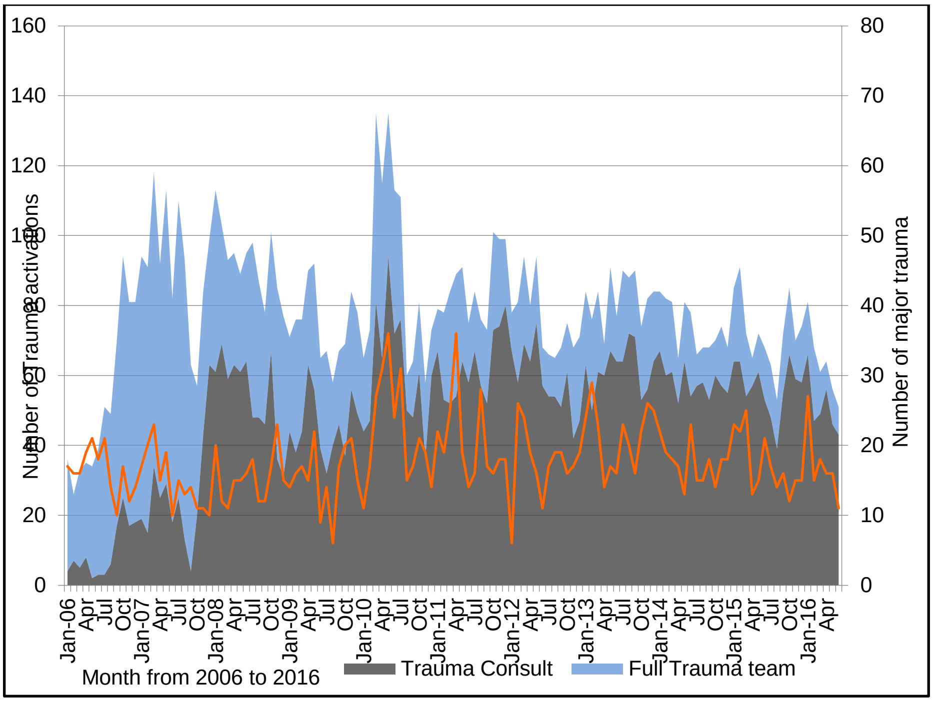

Figure 1 – Monthly counts of trauma team activations and major traumas between 2006 and 2016 after the implementation of routine audit of all trauma patients regardless of injury severity

DISCUSSION

Trauma registries are critical components of trauma systems and trauma centre care as they facilitate outcome evaluation and quality improvement through data collection and audit[12].The present study demonstrated the use trauma team activations as a measure of overall trauma centre activity. Most trauma registries have inclusion criteria based on injury severity[3]. This study represents a conceptual shift to a purely operational definition on trauma, one based on service delivery and trauma team activity, rather than an arbitrary severity score. This is the first study to demonstrate long term trends in overall trauma team activity at a single trauma centre.

This inclusive approach to defining trauma patients has a number of advantages. Firstly, as demonstrated in this paper, changes in hospital trauma activity can be readily reported. Changes in the NSW Ambulance major trauma triage protocol were associated with substantial increases in trauma team activity in 2010. These were much higher than predicted in the State Trauma Plan[11] as initial modelling reported in the plan did not account for increases in non-major trauma activity that grew by an even greater amount. Such information could be used to map out and predict changes in activity in the context of future State-wide trauma system changes, and evaluate hospital and pre-hospital triage protocols. Trauma triage is fundamental to the trauma system as it determines the transport of patients with potentially serious injuries to designated trauma centres. This is particularly important in inclusive trauma systems and has been shown to improve outcomes for major trauma[13,14]. It also influences local hospital trauma response. A recent study conducted in a US trauma centre demonstrated that the inclusion of age over 70 years as a sole criterion for full trauma activation reduced adjusted mortality for geriatric trauma[15]. To effectively evaluate prehospital trauma triage however, all trauma centres needs to collect a uniform minimum dataset of all trauma patients transported to hospital based on established trauma algorithms, regardless of eventual injury severity. An option that may facilitate this approach would be to establish data linkage of Emergency and in-patient hospital patient databases with Ambulance data registries[16]. Such options are currently being explored in Australia and New Zealand.

Secondly, all trauma patients at this institution and others were case managed by trained Trauma Clinical Nurse Consultants and Case Managers[17], using a quality framework similar to the one reported by Stelfox et al[18]. This allowed clinical issues such as delays to imaging or definitive management to be identified and rectified in any trauma patient regardless of injury severity before their recurrence in major trauma cases, where such variations in care are likely to be clinically significant. Over the past ten years this “bottom up” approach to quality management has been associated with a reduction in both missed injuries and risk adjusted mortality for major trauma (ISS>15)[9]. Collecting data on all trauma patients for the purposes of ongoing audit therefore makes clinical sense.

Thirdly this method of data collection allowed reporting of data that was more reflective of overall hospital trauma activity. All patients managed through trauma team activation necessitate paramedic and multidisciplinary specialist trauma team response with most going on to receive some form of imaging, observation and serial assessment in the Emergency Department. Modelling changes in clinical activity in a given trauma centre that occur with trauma system changes therefore need to account for the potential impact of all trauma arrivals, which as this report demonstrates largely comprises non major trauma. “Major trauma” itself is not a discrete clinical or diagnostic entity – it exists conceptually as a small part of a spectrum of injury disorders treated within trauma centres. For instance, a young patient who falls three metres from a ladder and sustains a splenic laceration and rib fracture may only score an ISS of 9, be managed on the ward non-operatively in combination with a semi-urgent angio-embolisation procedure and discharged within two days of admission. There is little doubt that this patient would benefit from trauma centre expertise and resources. As it stands this patient would not meet the criteria for most local and international trauma registries, with ramifications for establishing costs and funding models for trauma care at hospitals[19]. Recording only those patients with an ISS>15 would only account for little over 16% of the trauma system load at this hospital.

It is self-evident that data collection has as a result of this change, increased substantially since 2006. A typical trauma registry entry has over one hundred data elements and the average hospital trauma registry employs between one to three full time staff to enter data and ensure data quality[3]. At this institution, reporting of all trauma team activations was achieved with one full one full time data manager collaborating with one full time equivalent (FTE) Clinical Nurse Consultant and one FTE Case Manager (since 2010). The trauma registry at the Royal London Hospital is one example where the routine monitoring of trauma activations has facilitated improvement in activity and outcomes[20]. The quality improvement initiatives described above, and in hospitals like the Royal London would not have been possible if trauma patient data collection were not explicitly linked to quality improvement indicators, irrespective of injury severity. Injury surveillance is another key function of trauma registries. The Washington State Trauma Registry is an example of a state-wide registry that uses trauma team activation as a principal inclusion criteria[21], and this strategy has proved useful in the surveillance of particular categories such as occupational injuries. Other clinical registries that seek to evaluate systems and treatment of specific conditions, notably the Australian Stroke Registry[22] collect both complete strokes and transient ischaemic attacks, thus representing the entire spectrum of the condition it seeks to monitor.

The main limitation with the use of trauma team activation as the sole criterion was that it did not capture all patients with major trauma presenting to this hospital. Most trauma activation algorithms have an undertriage rate of 5-10%, depending on the gold standard definition of major trauma used[8], meaning that trauma systems will routinely miss around one in ten patients who had major trauma presenting to hospital but did not have a trauma activation. The triage protocol used in this study has an undertriage rate of 3%[8]. These were often elderly patients who presented with isolated head trauma, presented atypically or those who presented several days after the incident. It would therefore make sense to combine this definition with existing criteria for major trauma if the aim were to measure the full extent of major trauma at a hospital. Furthermore unless every hospital that receives trauma patients within a trauma system reports on all trauma activations, it will be difficult to evaluate the true rate of under and overtriage of prehospital trauma triage protocols.

Other potential limitations include variation in trauma team response criteria within trauma centres and across trauma systems, and the need for data managers to collect data on patients who have been clearly overtriaged with no injuries. Most mature trauma systems have uniform guidelines for prehospital trauma triage and transport to designated trauma centres within a given system[14]. Indeed the trauma team activation criteria reported here is almost identical to the American College of Surgeons criteria for trauma triage to a designated trauma centre[7]. Any variations in hospital based response are likely due to local constraints or reflect local rather than regional prehospital practices. Again these factors are important to track and report from a system point of view as they reflect the efficiency of system-wide wide trauma triage protocols and are likely associated with variations in system performance. Finally we did not perform data linkage of Ambulance and hospital patient data which would appear to reflect trauma activity at this hospital given that 94% and 85% of full trauma calls and trauma consults respectively are brought in by ambulance. This would be an important further investigation.

CONCLUSIONS

Inclusion of trauma team activation as a criterion for trauma registry data collection has facilitated evaluation of trauma system changes at an Australian major trauma centre over the past ten years. Trauma registries that seek to comprehensively evaluate trauma systems of care, including trauma triage should consider adding this criterion to enable a more operational definition of trauma based on service delivery within a system, rather than injury severity.

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CONTEMPORANEOUS TRENDS AND THE NSW TRAUMA SYSTEM

SYNOPSIS

The following chapters establish the context in which the trauma service at RPA functions. It begins by describing the current state of the New South Wales Trauma system, highlighting the role of Royal Prince Alfred Hospital as one of seven adult Major Trauma Centres illustrated by a hypothetical case study. This is followed by major works detailing the scope of injury and trauma activity across NSW. The purpose of this section is to describe the trauma system in detail for readers not familiar with trauma care in this state, describe the scope of trauma and injury management, present some of the major demographic trends affecting trauma patients, and describe contemporaneous trends in major trauma activity, changes in major trauma procedures, in particular with the advent of technologies such as Hybrid Operating Theatres, and mortality in New South Wales, by which mortality trends at Royal Prince Alfred Hospital may be compared in later chapters.

This chapter contains reprint of the following publications and submissions:

SCOPE OF INJURY PRESENTATIONS AND DEMOGRAPHIC TRENDS

- Dinh MM, Bein KJ, Berendsen Russell S, Muscatello D, Ivers R. Age-related trends in injury and injury severity presenting to emergency departments in New South Wales Australia. Accepted Injury August 2016

NSW TRAUMA SYSTEM AND MAJOR TRAUMA MORTALITY TRENDS

- Dinh MM, Bein KJ, Curtis K, Ivers R, Balogh Z, Seppelt I, Deans C, Rigby O. Rural and metropolitan major trauma mortality trends in 2009-2014 in New South Wales Australia: a retrospective study using a state-wide trauma registry. Accepted Med J Aust August 2016

NSW TRAUMA ACTIVITY AND MAJOR TRAUMA PROCEDURE TRENDS

- Oliver M, Dinh MM, Balogh Z, Paschkelwitz R, Curtis K, Rigby O. Trends in trauma procedures performed at Major Trauma Centres in New South Wales Australia. An analysis of State-wide trauma data. Submitted to ANZ Journal of Surgery, awaiting review June 2016

CHAPTER FIVE

THE NEW SOUTH WALES TRAUMA SYSTEM

New South Wales (NSW) is the most populous state in Australia with a population of around 7 million and a land area of over 800,000 square kilometres[1] (France is approximately 600,000 km^2). The trauma system in NSW aims to ensure that all injured patients with actual, potentially serious or complex injuries are identified, treated and transported to the most appropriately resourced trauma centre, receiving timely and evidenced based acute hospital care and rehabilitation – irrespective of location. Vast tracts of sparsely populated rural and remote areas together with the concentration of urban populations within the Greater Sydney Metropolitan Area and regional centres along the eastern seaboard creates unique challenges for the trauma system, particularly with respect to prehospital and retrieval transport across long distances and the optimal number and location of designated trauma centres. Other key features of the trauma system include the monitoring and improvement of clinical care through research and quality improvement, surveillance of injuries through data collection and advocacy of trauma and injury management through collaboration with government agencies and various other political and public health bodies. The system is therefore designed to not only maximise the chances of survival, but to optimise recovery and return to baseline health status. The following chapter describes the key features of the current NSW Trauma system that was instigated in 1991 and last revised in 2009[2], highlighting the role that Royal Prince Alfred plays within the current trauma system.

Components of the NSW trauma system

NSW Institute of Trauma and Injury Management (ITIM)[3]

This organisation exists within NSW Agency for Clinical Innovation as one of several clinical networks that include the Emergency Care Institute, Burns, Spinal Injury Radiology amongst others. The Clinical Director and Manager of ITIM reports to the Surgical and Critical Care subsection of the Agency for

Clinical Innovation. The roles of ITIM are the coordination of trauma services across NSW, clinical governance through guidelines and policies, monitoring of trauma system performance through the NSW State-wide registry, and trauma service planning and model of care provision through a network of sub-committees that report to the Executive Committee. Membership of committees is on a voluntary basis and there is representation from all Major and Regional Trauma Centres in one or more committees. These committees convene on a bimonthly basis and include;

- Clinical Review Committee – Peer reviewed trauma morbidity and mortality case reviews and clinical incidents
- Data Management Committee – Management of the State-wide trauma registry, including data definitions and inclusion criteria
- Research Committee – Peer review and facilitation of trauma related research projects
- Education Committee – Coordination and support of trauma education and training activities and agendas
- Clinical Indicators Committee – Peer review and implementation of various quality audit filters

State-wide Trauma Registry[4]

An online State-wide trauma registry was launched in 2009. Previous to this, each Major Trauma Centres would submit separate minimum datasets of major trauma to ITIM that would be collated manually on an annual basis. With the implementation of the "Collector" Registry, Major Trauma Centres could submit the minimum dataset into a secure online platform in real–time, automatically collating major trauma data across the state. Other advantages include the use of existing American College of Surgeons audit filters for quality assurance purposes and dual coding of injuries based on AIS and ICD-10AM codes. The current inclusion criteria for the NSW State-wide Trauma Registry are an Injury Severity Score >12 or death due to trauma. Minimum dataset requirements include mechanism of injury, location, vital signs at scene, mode of arrival, ambulance treatment and transport times, Emergency Department vital signs and treatment, injuries, procedures, Intensive Care Unit admission and hospital outcomes, including length of stay, survival and disposition from hospital. The trauma registry data entry is managed at each trauma centre by a trauma data manager and coordinated by the ITIM trauma data manager.

NSW Ambulance Service

The NSW Ambulance Service is one of the largest prehospital organisations in the world operating over 1000 ambulance vehicles stationed in over 260 locations including a specialist Aeromedical Retrieval Service located in Bankstown[5]. The Ambulance Service is a statutory authority responsible to the Ministry of Health, responsible for dispatching ambulances to the scene of injury in a timely manner via an ambulance coordination centre located in Redfern, and once there identifying potential major trauma using the T1 Major Trauma transport protocol[6]. All patients meeting criteria as specified in the protocol (based on abnormal vital signs, evidence of serious injury, severe mechanism of injury and other factors such as age or comorbidities) are to be transported to the nearest trauma centre if they are within 60 minutes transport time from the scene of injury. If given the distances involved, the patient is brought to a non-designated trauma centre, the Ambulance Service then coordinates the retrieval or inter-hospital transfer of that patient to a trauma centre if required.

Specialist Retrieval Services

There are currently two not for profit organisations, independent of NSW Ambulance Service that provide specialist medical retrieval services in NSW (Careflight and Westpac Rescue). Cases meeting trauma criteria are tasked to a given retrieval service using a tasking system operated by NSW Ambulance Service, and patients are treated and transported from the scene accompanied by a specialist retrieval doctor.

Trauma networks of care

Given the size of NSW, and the limitations of the trauma transport protocol described above, it is understandable that most major trauma patients do not present directly to a major trauma centre. Trauma networks were initiated to ensure that trauma patients in rural and regional areas of NSW had access to timely trauma centre care when required. They consist of usually smaller rural and regional hospitals that liaise directly with a designated lead trauma facility. These were consolidated in 2009 and represent defined pathways for trauma transfers from non-major trauma centres to a designated trauma centre within a given network (Tabled below)

Designated trauma centres

In NSW designated trauma centres consist of Regional Trauma Centres and Major Trauma Centres. Regional trauma centres are equivalent to Level 2 centres in the US and serve larger regional centres such as Port Macquarie, Orange and Wollongong. They are capable of providing definitive care in most instances of major trauma. There are seven adult major trauma centres located in metropolitan areas (Sydney and Newcastle) and two paediatric major trauma centres. Major Trauma Centres are large tertiary hospitals that not only provide state of the art trauma care but are capable of running research and quality assurance programs, demonstrate leadership in trauma management and referral systems across the state and within a given Local Health District. They are also supported by a full suite of medical and surgical subspecialties including Blood Bank and Haematology, Rehabilitation specialists, Critical Care and Interventional Radiology. Major trauma centres are typified by an organised process of trauma triage and trauma team activation in the Emergency Department followed by initial stabilisation using structured multidisciplinary team approach and resuscitation using defined protocols, definitive care and recovery of trauma patients. Modern trauma clinical care leverages many other services within the hospital including Diagnostic and Interventional Radiology, Surgical specialties (Orthopaedic, Neurosurgery, Cardiothoracic, Plastics, Urology, Maxillofacial and Vascular), Operating Theatre Management including Anaesthetics, Intensive Care Unit, and Rehabilitation. Other essential services include Blood Bank and Haematology, Allied Health, Medical Specialist services, Obstetrics and Neonatal services. Increasingly trauma services are collaborating with General Medical and Geriatric Services to adequately manage the growing case-load of elderly trauma patients. Within this framework, trauma services within Major Trauma Centres fulfil many roles, including clinical care and follow up, coordination of specialty services, case management, trauma education, audit and research. These roles are undertaken by a team typically comprising;

- Trauma Director – Typically a trauma experienced Surgeon or Critical Care physician who provides medical leadership, strategic direction and overall responsibility for clinical care
- Trauma Coordinator – typically a Clinical Nurse Consultant who coordinates day to day clinical management, education and quality management activities of the trauma department
- Trauma Case Managers – Conducts detailed reviews of case notes, identifies and follows up on clinical and incident reviews.
- Trauma Committee – comprises clinician representatives of key stakeholders within the hospital, including surgical subspecialties, Emergency, Intensive Care and Anaesthetics.
- Trauma Data Managers – Manages data collection and entry into the database and audits the quality of data field entry
- Trauma Fellow and Registrars – These are typically Registrars on the General Surgery training program or post-surgical fellowship candidates wishing to obtain additional exposure to trauma activity.

MAJOR TRAUMA SERVICE	REGIONAL TRAUMA SERVICE	REFERRING LOCAL HEALTH DISTRICT
JOHN HUNTER	Coffs Harbour Lismore, Port Macquarie, Tamworth, Tweed Heads	Hunter New England North Coast
ROYAL NORTH SHORE	Gosford	Northern Sydney, Central Coast
LIVERPOOL	NA	Sydney South West
ROYAL PRINCE ALFRED	NA	Sydney
ST GEORGE	Wollongong, Wagga Wagga	Greater Southern, South Eastern Sydney
WESTMEAD	Nepean, Orange	Sydney West, Greater Western
WESTMEAD CHILDRENS	NA	State-wide paediatric
SYDNEY CHILDRENS	NA	State-wide paediatric
ST VINCENTS	NA	South Eastern Sydney

Table 1 - Major trauma referral networks in New South Wales

Figure 1 - Location of major and regional trauma centres in New South Wales Australia - from NSW Agency for Clinical Innovation, NSW Institute of Trauma and Injury Management Annual Trauma Reports

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CHAPTER SIX

TRAUMA MANAGEMENT AT ROYAL PRINCE ALFRED HOSPITAL

Royal Prince Alfred Hospital is a 900 bed quaternary referral hospital and Major Trauma Centre located 5km from the Central Business District of Sydney, the largest city in Australia. The hospital is home to a 54 bed Intensive Care Unit, and 29 Operating Theatres making this one of the largest and busiest critical care and combined surgical services in the country. It is the state referral service for liver and kidney transplantation, melanoma surgery and the national referral service for pelvic exenteration and is one of two centres in NSW with a fully operational Cardiothoracic Extracorporeal Membranous Oxygenation (ECMO) service (http://www.slhd.nsw.gov.au/rpa/). There are three Interventional Radiology suites as well as a Hybrid Operating Theatre, which combines formal angiographic imaging capabilities within a conventional Operating Theatre room. The Emergency Department sees over 75,000 presentations annually making it the third busiest in NSW and has three resuscitation bays and 24 adult acute beds. A hypothetical case will be used to illustrate the journey for a “typical” trauma patient at RPA for readers not familiar with acute trauma management or the trauma system in NSW.

CASE STUDY

John is a 45 year old man who was struck by a truck whilst travelling on his motor bike on Parramatta Road, Strathfield at around 1600 on a Monday afternoon. He was wearing a helmet and protective clothing but was confused and screaming in pain. Traffic was stopped by police on all city bound lanes, bystanders were at the scene immediately and had called “000” for an Ambulance. A general duties ambulance crew arrived within 5 minutes and assessed John as follows: He had a left leg deformity and left chest pain. His pulse was 120 beats per minute, respiratory rate was 30 breathes per minute and blood pressure recorded was 80/40mmHg. A higher level backup crew was requested and a specialist retrieval team arrived at the scene at 1615. A left sided tension pneumothorax was identified and a finger thoracostomy performed to relieve it. They also inserted an intravenous cannula, applied a pelvic splint, leg splint and cervical collar. An ultrasound was performed (Focused Abdominal Sonography in Trauma FAST) which identified a small amount of intraperitoneal fluid. He was given 10mg intravenous (IV) morphine for analgesia as well as 15mg IV ketamine. His details were conveyed to the Ambulance Coordination Centre by the paramedic crew at the scene and the Major Trauma transport protocol (T1) was activated. This meant that the patient would need to bypass the nearest hospital (Concord Hospital around 10 minutes away) and transport the patient directly to Royal Prince Alfred Hospital (20 minutes away). The Royal Prince Alfred Hospital Emergency Department hotline was contacted and the resuscitation nurse in the Emergency Department contacted the paramedic team directly by two way radio. The patient’s current condition was conveyed to the resuscitation nurse who was told to expect the patient in 15 minutes.

On receiving this clinical information, the resuscitation nurse immediately spoke to the Emergency Consultant on duty who asked that a Full Trauma Call “Code Crimson Alert” be activated. The clinical information provided by the Ambulance crew fulfilled criteria for a Full Trauma Team activation according to the trauma triage protocol. Aside from mobilising senior clinicians from Surgery and Critical Care specialties (Senior Emergency Registrar, Trauma Clinical Nurse Consultant, Intensive Care Unit, Anaesthetics and General Surgery Registrars and Radiographers), the protocol notifies the Operating Theatre Nurse in charge of a likely operative case. Upon contacting the Emergency Department and receiving the details of the expected patient, the Operating Theatre Nurse discusses the impending case with the Anaesthetist on duty, who expedites current cases in the Emergency Operating Theatre (Theatre 1) and notifies the Hybrid Operating Theatre (Theatre 19) of a potential case. The Radiology Department is also notified and a CT scanner is left vacant in anticipation.

John arrived in the Emergency Department of Royal Prince Alfred Hospital at 1640 and was directed immediately to the resuscitation bay where the full trauma team was assembled in personal protective gear and trauma equipment trolleys ready. Roles were assigned to each team member - the Anaesthetics

Registrar would assess and manage the airway, Surgical Registrar would assess breathing and insert the chest drain and perform a secondary survey. The Intensive Care Registrar would manage fluid resuscitation and the Massive Transfusion protocol. A senior Radiology Registrar was present to help interpret initial imaging and expedite transfer for CT imaging and Interventional Radiology. The Emergency Consultant would be the team leader.

The retrieval doctor gave a one minute handover to the trauma team and the patient was then transferred to the resuscitation bed. A primary survey was immediately performed which revealed the following: His airway was patent, with reduced air entry to the left chest on auscultation. His blood pressure was 100/60 mmHg, pulse 120 beats per minute. His FAST was positive for free intraperitoneal fluid. A Chest X Ray showed a large pneumothorax and multiple left sided rib fractures. A Pelvic X Ray revealed pubic diastasis and right sacroiliac joint disruption consistent with an open book pelvic fracture. His Glasgow Coma Score was 13. A perineal examination revealed blood at the urethral meatus and he had evidence of an open femoral fracture.

The clinical summation from the Emergency Physician trauma team leader was that John had sustained a complex pelvic injury with pelvic haematoma and urethral disruption, compound left femur fracture, multiple left rib fractures and a tension pneumothorax. There was very likely a splenic laceration resulting in free intraperitoneal fluid and evidence of haemodynamic instability.

A chest drain was inserted on the left side and blood tests were sent for urgent cross match. Gentle traction was applied to the left leg with the pelvic splint on and a formal Code Crimson was activated at 1635. This protocol initiated the Massive Transfusion protocol and the Trauma Surgeon and Operating Theatres were simultaneously notified that a Code one operative Case was imminent and needed transfer to the Operating Theatre within 20 minutes. The Massive Transfusion protocol included the early transfusion of Fresh Frozen Plasma and tranexamic acid in a trauma patient with evidence of life threatening haemorrhage to prevent trauma coagulopathy. After discussion with the Trauma Surgeon on call, the patient is first transported to the CT scan for a trauma CT of the head, spine, chest, abdomen and pelvis. The patient was transported there at 1650 and the scan was completed at 1710. The initial report in consultation with a Trauma Radiologist were a Grade III splenic laceration with a small amount of haemoperitoneum, multiple left sided rib fractures with flail segments in 4 ribs, multiple pelvic fractures associated with a large pelvic and retroperitoneal haematoma with evidence of contrast extravasation on arterial phases. Delayed phase CT showed the possibility of an extraperitoneal bladder rupture. He was transported to the Hybrid Operating Theatre at 1720 for simultaneous embolisation of pelvic vessel haemorrhage, retrograde urethrogram and repair of bladder laceration, left femur fixation and prophylactic embolisation of a branch of the splenic artery.

John then spent one week in the Intensive Care Unit for postoperative management, close observation of his spleen injury and management of his chest injury. His stay was briefly complicated by an episode of pneumonia exacerbated by pulmonary contusion that was promptly treated with chest physiotherapy and intravenous antibiotics. On the day after his operation he was reviewed in the Intensive Care Unit by the Trauma Registrar, Data Manager and Clinical Nurse Consultant together with some medical students on rotation from The University of Sydney Medical School. On this ward round, he was reassessed by the trauma team who reviewed all his test results and progress. The trauma data manager entered his clinical and injury characteristics into the State-wide trauma registry. His Injury Severity Score was calculated at 41 classifying him as severe anatomic injury. The Trauma Clinical Nurse Consultant coordinated the care of John including organising Cardiothoracic consultation, Urology follow up for his bladder injury, ensuring venous thromboembolism and tetanus prophylaxis and adequate pain medications were charted and had been given to John whilst in hospital. The trauma team identified a number of clinical issues related to his care, including delayed management of his bladder injury. These were discussed at the weekly trauma unit meeting and it was decided that the trauma imaging protocol be revised and education about urogenital injuries in the context of pelvic trauma be discussed at the monthly trauma grand rounds.

John spent a further 3 weeks recovering on the wards and was transferred to a private rehabilitation facility, where he spent a further month receiving physiotherapy for his leg and pelvic fractures. He was followed up by specialist Orthopaedic and Urology clinics. When he was assessed by the trauma team after three months post discharge, he complained of ongoing post-concussion symptoms and evidence of post-traumatic stress. He was referred for further counselling and neurocognitive testing at the neurology clinic. After six months he was back to work full time and mobilising with mild to moderate pain. Although his treatment had been covered under compulsory third party insurance schemes, he did not have income insurance and was out of work for almost four months, whilst his wife had to support him and their two young children.

CASE DISCUSSION

The case describes the acute management and rehabilitation of a major trauma patient at Royal Prince Alfred Hospital to illustrate some of the salient features of the trauma system at this hospital. A number of interesting clinical features form the case stand out. Most importantly is the need for post discharge clinical information to inform trauma services regarding the ongoing care of patients after leaving hospital. This will be addressed in Chapter 13. Secondly Interventional Radiology now plays in the management of severe pelvic trauma and moderate to severe solid abdominal organ injury. This is a trend that has emerged only in the past decade and has transformed the management of once lethal injuries such as massive pelvic trauma. The following paper, currently under review, enumerates the increase in Interventional Radiology procedures occurring across NSW Major Trauma Centres over the past six years. As the paper discusses, this emerging trend has particular implications for the trauma system in NSW and across Australia.

CHAPTER SEVEN

Trends in trauma procedures performed at Major Trauma Centres in New South Wales Australia. An analysis of State-wide trauma data

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ABSTRACT

Objectives - To describe the trend in major trauma surgical procedures and interventional radiology in major trauma patients in Australia over the past 6 years

Methods - This was a retrospective review of adult major trauma (Injury Severity Score greater than 15) patients using the New South Wales Statewide Trauma Registry between 2009 and 2014. Major trauma surgical procedures were classified into abdominal, neurosurgery, cardiothoracic and interventional radiology. The proportion of patients undergoing such procedures per year was the outcome of interest.

Results - There were around ten thousand cases analysed. The proportion of cases undergoing interventional radiology procedures increased from 1% in 2009 to around 6% in 2014. Other major trauma surgical procedures remained stable. Only around 100 laparotomies were performed in 2014. The predictors of having an IR procedure performed were increasing year from 2009 (OR 1.5 95%CI 1.4, 1.6 $p<0.001$), hypotension (OR 1.5 95%CI 1.1, 2.1 $p=0.01$), severe abdominal injury (OR 4.2 95%CI 3.2, 5.3 $p<0.001$) and lower limb (including pelvic) injury (OR 3.8 95%CI 3.0, 4.7 $p<0.001$).

Conclusion - There has been a rapid increase in the use of interventional radiology over the past few years which will need to be addressed in future trauma service planning and models of care.

Keywords - trauma, surgical procedures, interventional radiology

INTRODUCTION

Over the last few decades there has been a move towards selective non-operative management (NOM) for the majority of solid abdominal organ injuries[1-6]. Together with improvements in access to diagnostic and interventional radiology in trauma centres over the past decades, this has resulted in a trend towards fewer open trauma surgical procedures by general surgeons such as exploratory laparotomy. Declining volume of these and other trauma related procedures has led to concerns regarding the viability, training and ongoing credentialing in Trauma Surgery and Emergency Medicine[7-12].

Although the relationship between operative trauma volume and outcome is complex, it is generally agreed that a certain volume of work is required to maintain the experience, processes and systems necessary to competently undertake urgent surgical, critical care and radiology procedures. This has particular implications for inclusive trauma systems where the volume of procedures performed in a given centre is further influenced by the number of designated trauma facilities. New South Wales (NSW) is the most populous state in Australia and is one such setting where seven adult Major Trauma Centres (equivalent to Level One Trauma Centres[13]) work to deliver trauma care in the context of declining road trauma, relatively static major trauma volumes and an ageing population[14].

There have been no studies describing overall trends in abdominal, cardiothoracic, neurosurgical procedures and interventional radiology procedures in major trauma centres in Australia. This study aims to review the number and trends of these procedures in major trauma patients using a State-wide trauma registry. This will better inform resource planning for State-wide trauma service delivery and future models of care within Major Trauma Centres in Australia.

MATERIALS AND METHODS

Design – This was a retrospective analysis using NSW State-wide trauma registry data.

Setting – The State-wide registry was established and maintained by the NSW Institute of Trauma and Injury Management and receives clinical and hospital outcomes data from seven adult major trauma centres and ten regional trauma centres[14]. Major trauma centres in NSW are equivalent to level one designated trauma centres and regional trauma centres equivalent to level two or three centres[14]. Two of the seven adult Major Trauma Centres have access to hybrid operating theatres that combine formal angiography facilities within an operating theatre[15].

Inclusion criteria – Adult patients (age ≥16 years) were included in this analysis if they presented to a Major Trauma Centre between 1 January 2009 and 31 December 2014 and had an Injury Severity Score (ISS) greater than 15.

Exclusion criteria – Patients were excluded if the postcode of injury was unknown or occurred outside NSW. Spinal and burns related procedures were excluded as one of two burns centres and one of two acute spinal units are not major trauma centres .

Data variables – Major trauma procedures performed at a Major Trauma Centres were categorised based on International Classification of Disease version 10 Australian Modification (ICD 10AM) codes into abdominal surgery (including laparotomy, laparoscopy, splenectomy, bowel surgery), neurosurgery (including craniectomy, burr hole and insertion of extra-ventricular drain), cardiothoracic surgery (including thoracotomy and thoracostomy, aortic repairs and cardiac surgery), interventional radiology (IR) (including digital subtraction angiography, peripheral angiography and angio-embolisation). Injuries were classified using Abbreviated Injury Scale codes into body regions and severe injuries classified as AIS score three or more[16].

Outcome – The outcome of interest was the proportion of major trauma patients who underwent a major trauma procedure.

Statistical analyses - Descriptive statistics were used for baseline characteristics and crude in-hospital mortality. Chi squared and Cochrane-Armitage linear trend tests were used to compare year by year differences and trends in major trauma procedures. Multivariable logistic regression was used to determine the adjusted odds of IR, adjusting for age, year of admission, hypotension (systolic blood pressure <90mmHg) access to hybrid operating theatre and severe body region injury. Analysis was performed using SAS Enterprise Guide version 6.1 (SAS Institute Cary NC).

Ethics - Approval was obtained from the NSW Population Health Services and Research Ethics Committee (2015/04/036).

RESULTS

Study population

A total of 18,652 cases were identified in the trauma registry of which 10,733 were adult patients treated at a major trauma centre with an ISS>15. The mean age (SD) was 53 (23) years and 71.8% were male. Table one summarises the baseline characteristics of the study population. The most common mechanisms of injury were falls (44.2%) and road trauma (37.5%) and the most common severe body region injured were head injury (56.6%) and chest injury (35.6%). Penetrating injury accounted for 3.7% of cases.

Figure two summarises the number of major trauma procedures performed at major trauma centres and demonstrates the rise in IR procedures performed for major trauma patients from around 1% in 2009 to 6% of all major trauma cases in 2014 (p<0.001). The proportion of major trauma patients undergoing Abdominal and Cardiothoracic Surgery has remained stable.

The predictors of having an IR procedure performed were increasing year from 2009 (OR 1.5 95%CI 1.4, 1.6 p<0.001), hypotension (OR 1.5 95%CI 1.1, 2.1 p=0.01), severe abdominal injury (OR 4.2 95%CI 3.2, 5.3 p<0.001) and lower limb (including pelvic) injury (OR 3.8 95%CI 3.0, 4.7 p<0.001). Admission to a major trauma centre with access to a hybrid operating theatre was not associated with increased odds of having an IR procedure performed (OR 0.9 95%CI 0.7, 1.1 p=0.38). Age and mechanism of injury were also not predictive for Interventional Radiology being performed.

Severe Abdominal Injury subgroup

In the 1045 patients with severe abdominal injury (abdomen AIS>2), the proportion of IR procedures has increased from 6% in 2009 to 23.5% in 2014 (p<0.001) whereas abdominal surgery has remained stable from 46.0% to 38.5% in 2014 (p=0.90).

DISCUSSION

The present study is the first to analyse major trauma procedure trends in Australia using a State-wide trauma registry. It clearly demonstrates the recent and rapid increase in IR procedures in major trauma patients. A number of factors may have influenced this increase, including the increasing role of IR in the acute management of abdominal and pelvic injuries, improvements in trauma triage and resuscitation, and improved CT scanning techniques with better solid organ injury grading, thereby facilitating non operative management.

The findings raise a number of concerns and implications related to the ongoing viability of training for both trauma surgery and trauma specific IR. Our study showed that there were around one hundred laparotomy cases in 2014 performed at seven adult Major Trauma Centres in NSW. This equates to around fifteen laparotomies per Major Trauma Centre, which given the number of surgical trainees and consultants working in acute surgery on a 24 hour roster, may be insufficient to maintain adequate training and experience. Grasberger et al. highlighted the need for surgical trainees to be exposed to a minimum of thirty operative trauma cases during their training period[16]. This arbitrary number has since been incorporated into the American Board of Surgeons recommendation that suggest ten operative cases and twenty non-operative critical trauma cases during training time, with the realisation that a larger proportion of trauma patients are managed non-operatively.

Some centres with large volumes may be able to achieve these recommendations, however when major trauma volumes are relatively low it would be less likely to occur. At institutions outside of the US, where penetrating trauma volumes are lower, doubts as to whether these targets are applicable remain[17]. There have been numerous articles that demonstrate an improvement in patient outcomes with larger volumes of patients[18-22] however, many studies also exist showing no difference and concerns have been raised about the methodological flaws of analysing patient volume against outcomes[23]. Therefore, it is controversial whether exposure to large volume of patients results in improved outcome of patients.

Secondly there are issues meeting the increased demand for IR in trauma and other acute specialties. The American College of Surgeons in the 'Resources for Optimal Care of the Injured Patient' recommendations state that Interventional Radiological Procedures must be available 24hrs a day and available within 30 minutes at Level 1 Trauma Centres[24]. A study by Schwartz et al. in 2014 found that patients suffering severe pelvic injury requiring IR arriving out-of-hours had an almost 100% increase in mortality (OR 1.94 CI 1.051- 4.967, p = 0.017) compared to those patients arriving in-hours. One of the main factors hypothesised for this difference was time to IR, which was significantly lower in the in-hours group compared to the out-of-hours group (mean time 193mins vs 301min respectively p = <0.001)[25]. Other authors have demonstrated differences in trauma mortality associated with delays to IR[26,27]. Given the growing demands and adoption of IR in the management of critically injured patients, providing a sustainable IR service, particularly out of hours, is challenging. There are a limited number of Interventional Radiologists and training positions in Australia and overseas, leading to challenges in providing appropriate after hours and on-call coverage[28].

It should be noted that this study examined trends in major trauma procedures based on data submitted to the State-wide trauma registry. It did not reflect orthopaedic procedures, which are likely to dwarf other trauma related procedures, or even procedures in patients with serious and penetrating injury where the ISS is less than 16. Other acknowledged limitations include the potential for bias with respect to the accuracy and completeness of procedure coding by individual trauma centres. For instance, the data was unlikely to be complete for trauma procedures such as airway intubation, chest drain insertion and vascular access procedures performed prior to arrival or in the Emergency Department. This may have changed over the course of the study period as the State-wide trauma registry underwent a transition between 2009 and 2011. We also did not include other surgical procedures performed by plastics, maxillofacial, vascular and other surgical subspecialties. Finally it was too early to determine if the increase in use of IR for major trauma has led to a decrease in laparotomy rates. The data from after 2012 suggests a decrease in laparotomy rates but will need to be monitored for a few years to evaluate ongoing trends and its effect on patient care and outcomes.

In conclusion, we report a significant increase in interventional radiology procedures performed in major trauma patients in NSW Australia, which reflects its growing role in contemporary trauma management. Consideration needs to be given to access and training in trauma specific interventional radiology as well as to the declining exposure in invasive abdominal trauma surgery.

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TABLES AND FIGURES

		N =10733 (%)
Age	15-24years	1567 (14.6)
	25-44years	2687 (25.0)
	45-64 years	2574 (24.0)
	65-84 years	2824 (26.3)

	≥ 85 years	1081 (10.1)
Gender	Male	7706 (71.8)
Mechanism	Road trauma (vehicle, cyclist, pedestrian)	4021 (37.5)
	Falls	4746 (44.2)
	Blunt assaults	619 (5.8)
	Penetrating	397 (3.7)
	Burns	209 (2.0)
	Other	868 (8.1)
Severe injury	Head	6074 (56.6)
	Chest	3825 (35.6)
	Abdomen	1045 (9.7)
	Spinal	1344 (12.5)
	Upper limb	145 (1.4)
	Lower limb(including pelvis)	1750 (16.3)
Major trauma procedures	Abdominal	675 (6.3)
	Neurosurgery	841 (7.8)
	Cardiothoracic Surgery	227 (2.1)
	Interventional Radiology	386 (3.6)
	Orthopaedic Surgery	1272 (11.9)
ICU and hospital length of stay	Intensive Care Unit admission	4769 (44.4)
	0-3 days	2205 (20.6)
	3-7 days	2337 (21.8)
	8-14 days	2432 (22.7)
	15-30 days	2098 (19.6)

	>30 days	1657 (15.4)
Outcome	Discharged to rehabilitation	3455 (32.1)
	Died	1505 (14.0)

Table one – Baseline characteristics of major trauma patients in New South Wales Australia

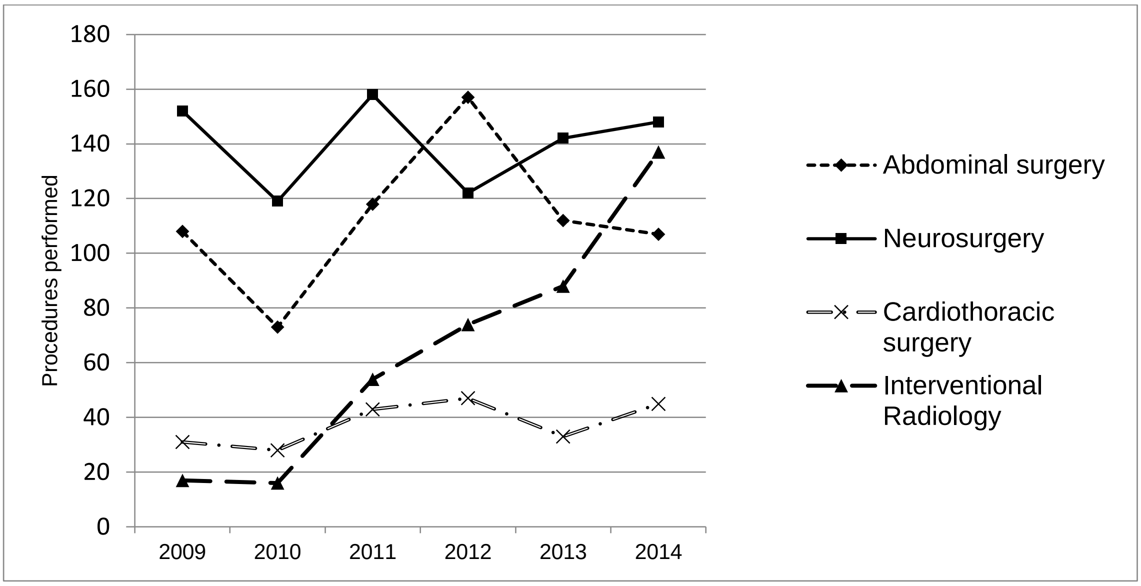

Figure one – Trends in major trauma procedures in New South Wales, Australia 2009-2014

CHAPTER EIGHT

AGE-RELATED TRENDS IN INJURY AND INJURY SEVERITY PRESENTING TO EMERGENCY DEPARTMENTS IN NEW SOUTH WALES AUSTRALIA: IMPLICATIONS FOR MAJOR INJURY SURVEILLANCE AND TRAUMA SYSTEMS

KEYWORDS - Injury, Emergency Department, Trauma

ABSTRACT

Objectives: To describe population based trends and clinical characteristics of injury related presentations to Emergency Departments (EDs).
Design and Setting: A retrospective, descriptive analysis of de-identified linked ED data across New South Wales, Australia over five calendar years, from 2010 to 2014.
Participants: Patients were included in this analysis if they presented to an Emergency Department and had an injury related diagnosis. Injury severity was categorised into critical (triage category 1-2 and admitted to ICU or operating theatre, or died in ED), serious (admitted as an in-patient, excluding above critical injuries) and minor injuries (discharged from ED).
Main outcome measures: The outcomes of interest were rates of injury related presentations to EDs by age groups and injury severity.
Results: A total of 2.09 million injury related ED presentations were analysed. Minor injuries comprised 85%, and 14.1% and 1% were serious and critical injuries respectively. There was a 15.8% per annum increase in the rate of critical injuries per 1000 population in those 80 years and over, with the most common diagnosis being head injuries. Around 40% of those with critical injuries presented directly to a major trauma centre.
Conclusion: Critical injuries in the elderly have risen dramatically in recent years. A minority of critical injuries present directly to major trauma centres. Trauma service provision models need revision to ensure appropriate patient care. Injury surveillance is needed to understand the external causes of injury presenting to hospital.

INTRODUCTION

Injury remains a leading cause of morbidity and mortality around the world[1] and accounts for almost one quarter of Emergency Department (ED) presentations in Australia.[2] Trauma systems have been shown to improve outcomes for severely injured patients, but monitoring and improving the effectiveness of trauma systems requires robust data collection at a population level.[3] Whilst data relating to hospital outcomes for severe trauma is routinely collected from designated trauma centres, the patients presenting to non-trauma centres are less robustly accounted for. This has the potential to affect the applicability of the age –related trends seen in trauma registries to regions, populations or non-trauma centre hospitals.[4] Use of ED presentation data, can potentially provide this information, though there are limited studies of population based injury trends using this type of data.

ED presentation databases have the advantage of capturing all injury related presentations regardless of disposition, severity of injury and hospital designation.[5] This is important given the majority of patients who present are seen and discharged from ED.[6] Compared to ED databases (unless data linkage is performed), inpatient and trauma registry data have greater detail in terms of diagnostic codes and hospital outcomes data.[7] Nevertheless, ED databases enable a broad description of epidemiological trends and clinical characteristics such as urgency, disposition and mode of arrival. These are necessary for surveillance of particular injuries such as burns, occupational injury, and geriatric trauma, and to identify gaps in a given trauma system that require additional support.[7,8] This has particular implications for current and future trauma and pre-hospital service planning in rural and remote locations. This is especially true given the current concentration of Major Trauma Services in urban environments[4], and the need for these to network with smaller hospitals serving rural and regional areas.

We sought to describe population based trends and clinical characteristics of injury related presentations to EDs, and to compare clinical characteristics of injury presentations to EDs within major trauma centres and non-trauma centres.

MATERIALS AND METHODS

Design and setting – This was a retrospective, descriptive analysis of de-identified linked Emergency presentations across NSW over five calendar years, 2010 to 2014. New South Wales is the most populous state in Australia, with seven designated adult major trauma centres, two specialist major paediatric trauma centres and ten regional trauma centres.4 Around 72% of the population live in metropolitan areas of New South Wales with a further 20% residing in inner regional and 8% in remote or outer regional locations and these have not changed significantly during the study period[9].

Data sources

The Emergency Department Data Collection (EDDC) registry contains routinely collected administrative and clinical data for patient level presentations across all public hospital emergency departments in NSW. Probabilistic linkage was performed by the NSW Centre for Health Record Linkage (CHeReL) to obtain patient level data across all sites and avoid double counting of patient encounters due to transfers between facilities[6]. Data obtained for this analysis included arrival mode, patient registration, type of visit, triage category, mode of separation, and the ED diagnosis entered made at the time of discharge. Estimated Residential Populations (ERP) by age and sex, per year, were obtained from the Australian Bureau of Statistics[9] and used to calculate age specific population rates.

Patient population – Patients were included in this analysis if they presented to an Emergency Department and had an injury related diagnosis recorded by clinicians as their primary ED diagnosis based on Systematized Nomenclature of Medicine Clinical Terms (SNOMED-CT) concept identifiers, or Australian clinical versions 9 or 10 of the International Classification of Diseases (ICD). Patients transferred from other health facilities were excluded to avoid double counting of presentations and patients who were dead on arrival were also excluded. A number of small rural Emergency Departments (n=35) were excluded due to incomplete data submission in 2010-11 to minimise bias in reported trends. Patient presentation was used as the unit of analysis to measure workload on ED, not individual level risk.

Data variable definitions - A full list of data definitions and data collection methods for the EDDC were available at http://www0.health.nsw.gov.au/policies/pd/2009/PD2009_071.html.
Emergency Department levels were defined using current NSW Ministry of

Health role delineations for public hospitals, which take into account the complexity of clinical activity and the staffing and support services at a given hospital[10]. These ranged from Level 6 being tertiary referral centres to Level 1 small rural multi-purpose centres. For the purposes of this study, hospitals were divided into Major Trauma Services (n=9, Adult and/or Paediatric centres), Tertiary non major trauma centres (n=17, Level 5 or 6 Emergency Departments, including all regional trauma centres but excluding major trauma centres), and other non-trauma centres (n=89, all other facilities). Major and regional trauma centres were identified using the current NSW State Trauma Plan[4]. Presenting problems entered at the time of patient arrival to ED by triage nurses, and ED diagnoses entered by treating physicians were categorised into broad diagnostic groups by the investigating team based on the relevant coding system (ICD10AM codes S00.0-S99.9, T00.0-35.7, T79.2-79.9, V01.00-Y05.99, Y20.00-34.99 mapped to equivalent codes in ICD9CM and SNOMED terms). Examples of these injuries included but were not limited to burns, lacerations, sprains, strains, fractures, falls and trauma. If an ED diagnoses was not recorded, the investigating team used the presenting problem to classify injury. Only 0.7% of the dataset had an ED diagnosis or presenting problem that could not be classified.

The Australasian Triage Scale (ATS) was used to define urgency with category one indicating immediately life-threatening, category two indicating imminently life-threatening, category three indicating potentially life threatening, category four and five indicating potentially serious and less urgent presentations respectively.[11] Patient details including age, gender and Indigenous status were recorded at the time of patient registration in the ED.

Injury severities were categorised, based on ED measures of urgency and mode of separation, into critical (presenting with triage category one or two and admitted directly from ED to the Intensive Care Unit or operating theatre, or died in ED), serious (admitted as an in-patient, excluding above critical injuries) and minor injuries (discharged from ED). These categories were used instead of diagnostic codes or injury severity because we wanted to investigate workload and complexity in ED rather than post hoc measures of injury severity.

Outcomes

Outcomes of interest were rates of injury related presentations to Emergency Departments by age group and injury severity. These were reported by calendar years.

Statistical analysis

Annual rates of change for each age group were calculated using the compound interest formula $[(P_1/P_0)^{1/n})-1]*100$ where P_1 is the final rate P_0 the initial rate and n denoting the number of years[12]. Chi square tests were used to compare characteristics between trauma centre designations. Population data for the Sydney Statistical Division was obtained from the Australian Bureau of Statistics[9] Categorical variables were compared using Chi squared tests. Incidence rate ratios (IRR) for age specific trends in presentation counts were estimated on aggregated data using generalised negative binomial regression using population as the exposure variable. Statistical analyses were performed using SAS Enterprise Guide version 4.3 (SAS Institute Cary NC). Age specific rates per 1000 population were calculated and plotted using Microsoft Excel.

Ethics

Approval for access to de-identified data was obtained through the NSW Population & Health Services Research Ethics Committee and the Aboriginal Health and Medical Research Council Ethics Committee**.**

RESULTS

Patient population

There were 10.8 million ED presentations identified during the study period of which 2.09 million (19.4%) had an injury related primary ED diagnosis. The next most common ED diagnosis categories were abdominal/gastrointestinal (12.5%) and respiratory (8.9%) and cardiovascular (8.0%).

Around 1.5 million individuals accounted for the 2.09 million presentations to EDs with injuries meaning that 74.8% of patients presented only once during the study period. Of all injury presentations, males comprised 59.1% of the study population, 22.1% were transported by ambulance and the overall in-patient admission rate was 16%. With respect to injury severity, 1777851 (85.0%) were minor, 294479 (14.1%) were serious and 19873 (1.0%) were critical injuries. The rate of critical injuries increased overall by 10.4%, serious injuries by 12.6% and minor injuries by 5.3% per annum.

Figure one shows age (5 yearly intervals) specific rates of injury related presentations to ED between 2010 and 2014 demonstrating peaks in paediatric age groups and those older than 80 years of age. There was an apparent increase in presentation rates in all age groups which was most pronounced in those over 85 years of age.

Figures two to four show the change in presentation rates by broad age group and injury severity, and demonstrates the rapid increase in critical and severe injuries in those over 80 years of age (and relatively stable trend in other age groups). In particular for critical injuries, annual rates of increase are shown in table one.

Critical injuries and trauma centre designation

Table two compares the patient characteristics with respect to trauma designation of the presenting hospital for the subset of critically injured patients (n=19,873). Of these, 40.8% presented to a major trauma centre, 22% to a tertiary non-major trauma centre and 37.2% presented to other hospitals. Patients presenting to major trauma centres were older and more likely to be transported by ambulance compared to those at other non-trauma centres. Around half of all critical injuries presenting to tertiary non-major trauma centres and 83% of those presenting to other hospitals were transferred to another facility. There were higher proportions of head and abdominal/pelvic injuries in those presenting to tertiary non-major trauma centres compared to major trauma centres (4.3% versus 3.7%). Of the 1747 patients aged 80 years or over who had critical injuries, 6.0% were referred by a nursing home or other aged care facility, and the three most common injury diagnosis types were head injury (30%), lower limb (10.8%), and chest injury (8.3%).

DISCUSSION

This is the first Australian study to identify the trends and characteristics of all injuries presenting to ED at a state-wide level. Although increases in injury presentations were in general observed across all age groups from 2010-2014, the study highlighted a dramatic shift in the rate of critical and serious injuries in patients 80 years and over. The findings from this study has important implications for future trauma service planning and broader injury management and prevention policies.[13]

Studies have pointed to the increase in proportion and cost of geriatric trauma.[14] Trauma service plans and injury management strategies in general need to take into account these demographic changes. It is clear that older trauma patients have increased mortality and morbidity for a given injury severity.[15]The management of the elderly population tends to be more complex owing to medical comorbidities, polypharmacy (including anticoagulation), social circumstances, and the need for longer recovery times and rehabilitation after injury. Given the management complexity of injured elderly patients, surgically-based trauma services may need to include greater emphasis on medical management. These may evolve from separate trauma-geriatric models of care, similar to ortho-geriatric services, to specific geriatric injury networks and referral pathways.[16] Other issues that need addressing include post discharge community support, sub-acute care and palliation for patients with advanced care directives or in whom aggressive trauma management is deemed futile.

Furthermore, the large number of presentations of patients categorised as 'critically injured' to non-major regional trauma centres requires further investigation. Currently data for severe injuries (Injury Severity Score >12), is collected only from Major Trauma Centres.[17] However, the data presented here suggests that the burden of initial treatment is shared across other hospitals, and including data from these hospitals increases the estimate of the numbers of severely injured patients in New South Wales. A substantial proportion of critically injured patients presented to "other hospitals" and the majority of these were rural hospitals with limited direct access to the metropolitan major trauma centres. The number of Major Trauma cases reported by NSW Major Trauma

Centres in 2013 was 3,411 (Injury Severity Score >12)[17] whereas the number of critical injuries in the same year identified in our study was 43.5% higher (4881 cases). The distribution of critical injuries across all types of facilities in this study highlights the need for a coordinated system of care and data collection across the state. Ambulance transport accounts for 43% of critically injured patients presenting to non-trauma/non-tertiary centres. These are largely smaller rural centres where access to ambulance and retrieval services may be lacking and where improved pre-hospital services may lead to direct transportation to more appropriate regional and major trauma centres. An effective retrieval and inter-hospital transport service has been shown to reduce mortality in severely injured patients.[18]

The definition of critical injury used in trauma registries is typically based on post admission injury severity scores.[4] The definition used in our study is based on death or the allocation of a high urgency triage category together with the need for transfer, operating theatre or intensive care unit admission. This reflects those requiring urgent or complex specialist interventions in the ED context. Moreover the 3% mortality of these critically injured patients of observed in this study is consistent with that reported in a study of patients transported on ambulance major trauma transport protocols.[19] further study linking this data to major trauma data of the same patient group will help establish the validity of this definition of injury severity with respect to the anatomic injury scores used in trauma registries.

Given the large proportion of injury presentations treated and discharged (85%) from ED, and the lack of detailed external cause of injury data recorded in ED systems, there is a significant gap in our knowledge about the true burden of injury in Australia.[20] Injury surveillance systems which include external cause data are essential to injury prevention through the identification of the numbers, causes, mechanisms, and risk factors for injury,[21,22] and routine emergency department patient databases in Australia do not facilitate injury surveillance. There are some advances in mining the presenting problem text which is commonly recorded in ED data which may allow for further interrogation of ED data, however for more systematic injury surveillance purposes the inclusion of a designated data field to capture external cause of injury coded data in ED systems is needed.[23,24]

Besides the definition of critical and severe injuries, another limitation to the study is the use of injury based ED diagnoses. These are likely to underestimate the true rate of injuries because symptom-based diagnoses such as ankle pain or chest wall pain were specifically excluded from the injury category used. As the analysis was performed on presentations and not patients we did not account for any representations of the same individuals. These are particularly relevant in the elderly who are more likely to return with, for example, recurrent falls. However, on a clinical and health service level, the assessment and treatment of injured patients, in general, is not impacted by the number of times they represent.[25]

This study highlights the need to urgently address trauma models of care, trauma service provision, and referral networks to ensure quality service provision for the growing demand on injury care. ED-based injury surveillance, which includes external cause data and short text-based injury descriptions are also needed to better understand the causes of injuries to allow the targeting of prevention activities to reduce the high rate and growth in geriatric trauma.

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FIGURE LEGENDS

Figure 1 – Age specific rates of injury presentations to Emergency Departments in New South Wales for calendar years 2010 and 2014. Data source: NSW Emergency Department Data Collection Registry

Figures 2 – Yearly trends in age specific rates of critical injury presentations to Emergency Departments in New South Wales for calendar years 2010 and 2014. Data source: NSW Emergency Department Data Collection Registry

Figures 3 – Yearly trends in age specific rates of serious injury presentations to Emergency Departments in New South Wales for calendar years 2010 and 2014. Data source: NSW Emergency Department Data Collection Registry

Figures 4 – Yearly trends in age specific rates of minor injury presentations to Emergency Departments in New South Wales for calendar years 2010 and 2014. Data source: NSW Emergency Department Data Collection Registry

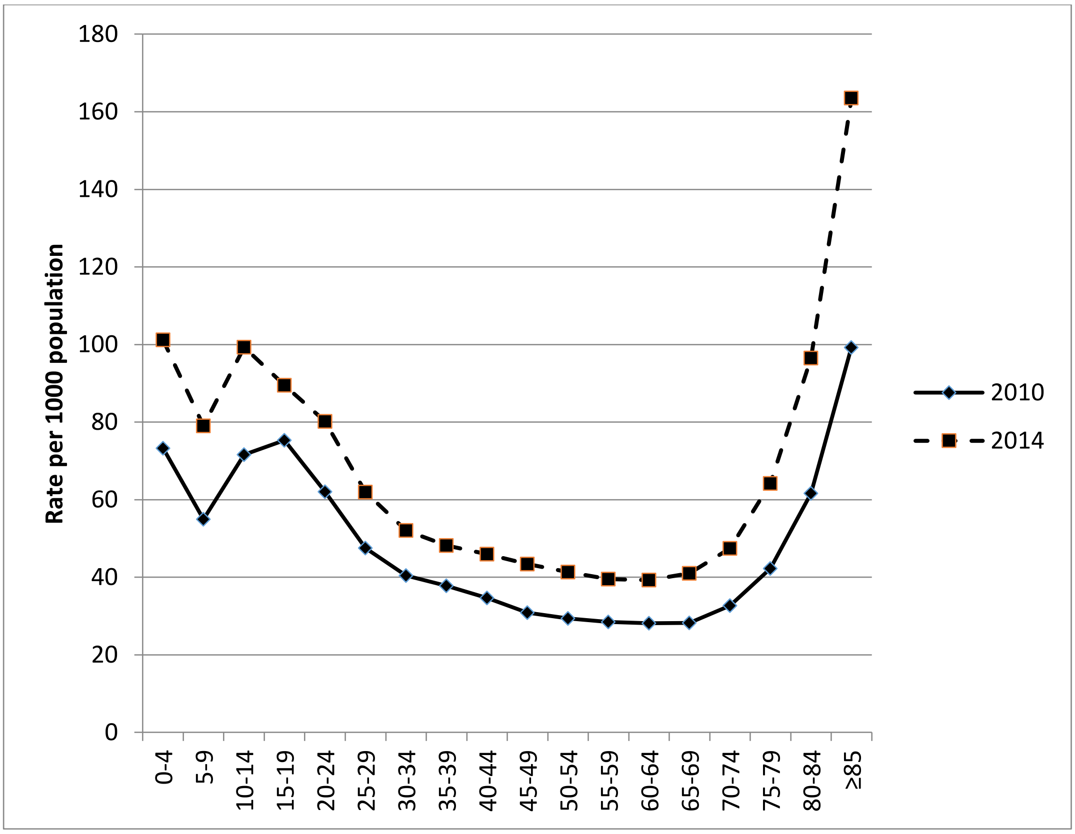
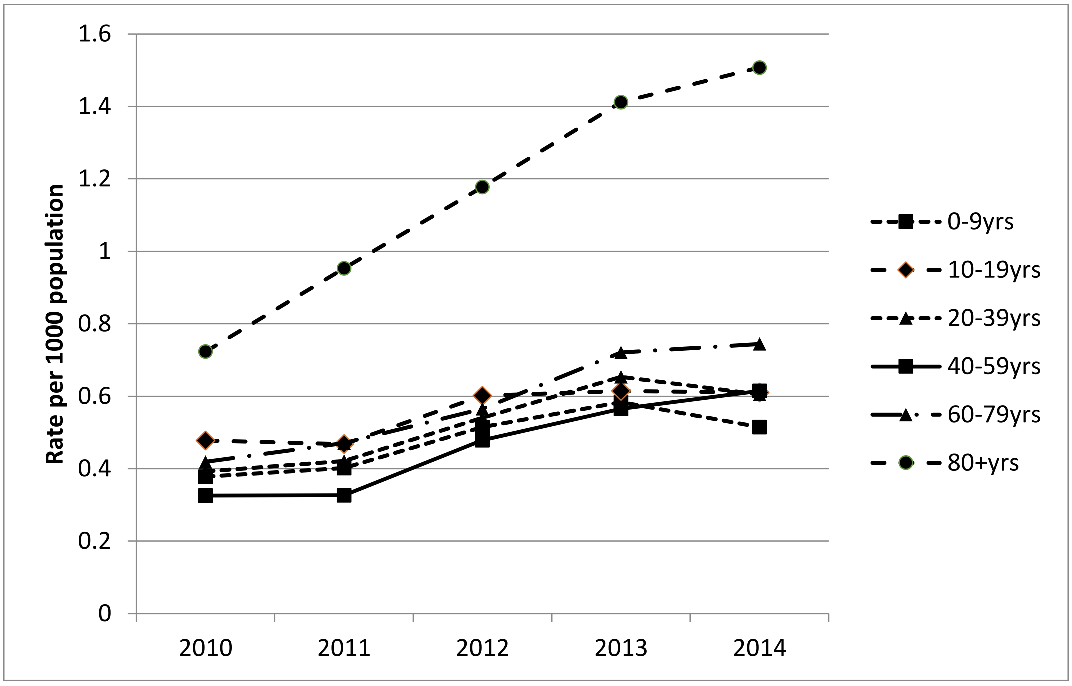


Figure 1 (above) and Figure 2 (below)



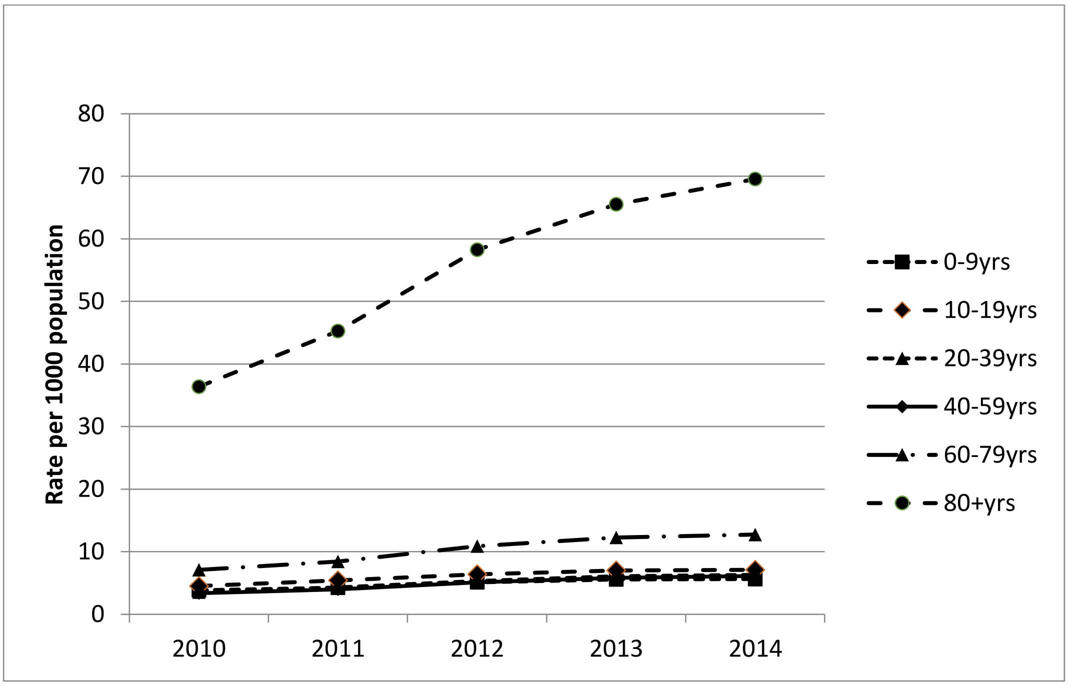
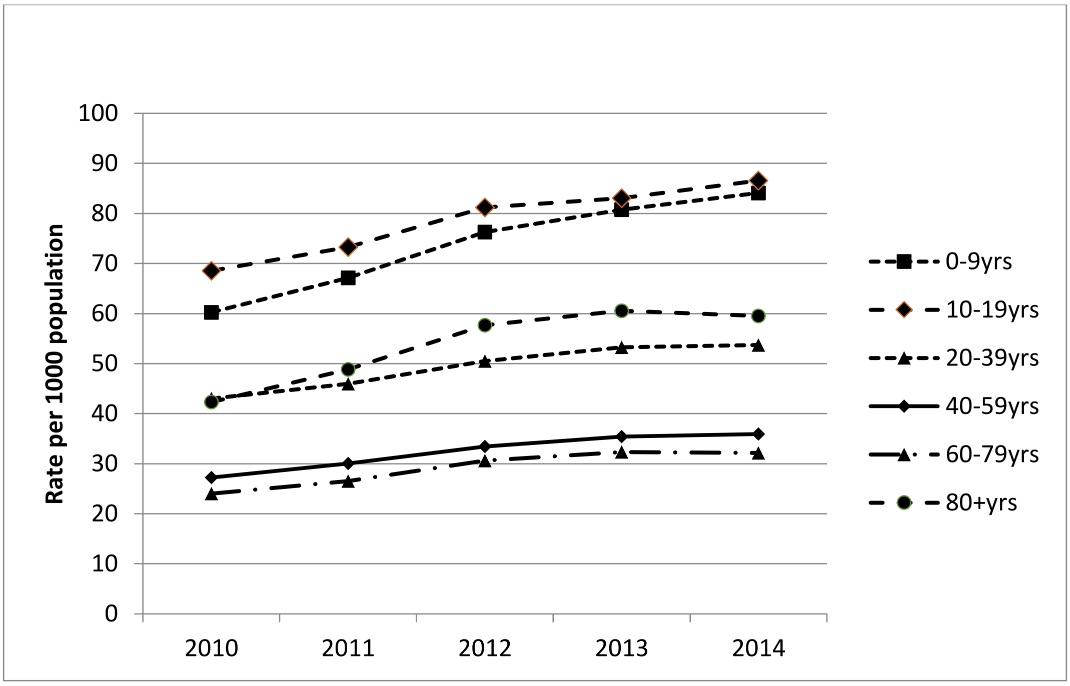


Figure 3 (above) and figure 4 (below)



CHAPTER NINE

Rural and metropolitan major trauma mortality trends in 2009-14 in New South Wales Australia: a retrospective study using a state-wide trauma registry.

Authors

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Conflicts of interest

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AUTHORSHIP CONTRIBUTION STATEMENT

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ABSTRACT

Objective: The aim was to describe trends in crude and risk adjusted mortality in major trauma patients injured in rural locations and those injured in metropolitan New South Wales (NSW) Australia between 2009 and 2014.

Design: A retrospective analysis using the NSW State-wide trauma registry.

Setting: NSW, Australia.

Participants: Adult patients with major trauma (Injury Severity Scores >15) were analysed with respect to trends in in-hospital mortality.

Main outcome measures: The main co-variate of interest was location of injury. In-patient mortality was adjusted using multivariable logistic regression.

Results: A total of 11423 eligible cases were analysed. For those injured in metropolitan locations, in-patient mortality was 14.7% in 2009 and 16.1% in 2014 (p=0.45). Major trauma in rural locations was associated with a statistically significant decrease in in-hospital mortality from 12.1% in 2009 to 8.7% in 2014 (p=0.004). Risk adjusted mortality decreased for those injured in a rural location in 2013 compared to 2009, and remained stable for those injured in metropolitan locations

Conclusion: Crude and risk adjusted mortality after major trauma have remained stable in those injured in metropolitan areas of New South Wales between 2009 and 2014. There was an apparent downward trend in rural/regional trauma locations which requires further analysis.

The known: Trauma systems facilitate the timely treatment of major trauma patients at trauma centres and this approach has been shown to reduce trauma patient mortality in several Australian states and internationally, however rural trauma has been associated with increased mortality rates.

The new: Trauma system changes introduced in New South Wales (NSW) since 2009 were associated with a decline in crude and adjusted in-patient mortality after major trauma in a rural location

The implications: Rural trauma transfer and retrieval networks together with improved trauma care at major trauma centres may be benefitting severely injured patients across rural and regional locations across NSW

INTRODUCTION

Injury continues to impose significant physical and psychological disability across around the world[1,2], and cost-effective systems of care are important to maximise patient outcomes and recovery. Trauma systems facilitate the timely treatment of severely injured patients and this approach has been shown to reduce trauma patient mortality in several Australian states[3,4] and internationally[5,6]. A system for trauma care was introduced in Australia in New South Wales (NSW) in 1991 and the first analyses of NSW major trauma outcomes were conducted in 2012[7,8]. In that study there was a survival benefit associated with definitive care at designated major trauma centres, located in NSW metropolitan areas[8].

A number of factors may have influenced patient outcomes in rural and regional trauma patients, particularly sparse population density and vast distances often required to transport many rural and regional trauma patients. Studies from other parts of Australia have demonstrated that rural trauma have worse outcomes compared to metropolitan trauma patients and it is well known that road crashes in rural and remote locations are associated with higher risk of death and severe injury [9,10]. The NSW Trauma minimum data set now includes additional data points including those from a number of regional centres [11] allowing more detailed analyses of outcome trends by location of injury occurring after 2009.

This was particularly relevant given the revision of the NSW State Trauma Plan which was implemented in 2009 which formalised rural and regional referral networks for each of the seven adult Major Trauma Centres[12]. The aim of these networks were to facilitate the timely transfer of severely injured patients from sparsely populated rural and remote areas of NSW to Major Trauma Centres which are all located in metropolitan areas along the east coast of the state. We therefore sought to assess and compare trends in crude and risk adjusted mortality between 2009 and 2014 in the context of these changes designed to improve trauma care and patient outcomes in NSW.

METHODS

Design – This was a retrospective analysis using state-wide trauma registry data.

Setting – NSW is the most populous state in Australia with a population of 7.5 million in 2014 and a land mass of 809,000km^2. Around 70% of the population lives in metropolitan areas along the eastern seaboard[13]. The State-wide registry was established and maintained by the NSW Institute of Trauma and Injury Management and receives data from seven adult major trauma centres and ten regional trauma centres[11]. Major trauma centres in NSW are equivalent to level one designated trauma centres (the highest possible designation) and regional trauma centres equivalent to level two or three centres according to the American College of Surgeon standards [14].

Inclusion criteria – Adult patients (age ≥16 years) were included in this analysis if date of presentation to a NSW hospital was between 1 January 2009 and 31 December 2014 and their Injury Severity Score (ISS) was greater than 15.

Exclusion criteria – Data were excluded from centres that did not submit data across all study years. Patients were also excluded if the postcode of injury was unknown or occurred outside NSW and those who were dead on arrival to hospital. Duplicate records of patients who were transferred between hospitals were identified and excluded if the referral hospital was a hospital that provided trauma data to the NSW Trauma Registry.

Data variables – Variables included basic demographic characteristics, mechanism of injury, vital signs on arrival, injuries length of stay (LOS) and in-hospital mortality. Injuries were classified using the Abbreviated Injury Scale (AIS) which is an anatomically based injury coding system. The AIS codes various injuries into anatomically distinct regions (head, neck, chest, abdomen, lower limb, upper limb, external) and assigns a severity score from one to six based on the likelihood of death and disability. Severe injuries in this study were classified as AIS scores of three or more[15]. The Injury Severity Score which was used to assess overall anatomic injury severity, was then calculated by summing the squares of AIS severity scores in the three most severely injured body regions. Major trauma for the purposes of this study was defined as an ISS>15. Hospital resource use measures included inter-hospital transfer, major trauma procedures recorded at referring hospital, Ambulance or Retrieval Services or trauma centre. For the purposes of this study patients were classified by the postcode location of the injury. These were categorised into metropolitan, inner regional, outer regional/remote locations based on Australian Statistical Geography Standard Remoteness Structure[16]. Due to the small number of deaths in outer regional/remote postcodes, all non-metropolitan postcodes were classified as rural/regional for the purposes of multivariable analyses.

Outcome – The primary outcome was in-hospital mortality after major trauma based on location of injury.

Statistical analyses - Descriptive statistics were used for baseline characteristics and crude in-hospital mortality. Chi squared and Cochrane-Armitage linear trend tests were used to compare year by year differences and trends in crude in hospital mortality. Risk adjusted mortality trends were calculated using logistic regression models stratified by injury location and adjusted using age, injury severity, ICU admission and year of admission. Variables were included in models based on preceding univariate analyses, or identified as influencing the risk of the mortality in adult injury patients in previous studies[8]. Adjusted Odds Ratios (OR) for in-patient mortality determined through separate rural and metropolitan location regression models were plotted on a line chart to show the trend in ORs relative to reference year 2009. Therefore ORs below one indicated improvement in adjusted in-patient mortality since 2009. Analysis was performed using SAS Enterprise Guide version 6.1 (SAS Institute Cary NC).

Ethics - Approval was obtained from the NSW Population Health Services and Research Ethics Committee (2015/04/036).

RESULTS

Study population

There were 18652 patients identified in the trauma registry between 2009 and 2014. After excluding those with an ISS <16, unknown or interstate injury postcodes and those from centres that did not submit data throughout 2009-2014 were excluded, 11,423 adult patients with ISS >15 were analysed (Figure one) from seven adult Major Trauma Centres and three Regional Trauma Centres.

With respect to location of injury, 8878 (77.7%) cases were metropolitan, inner regional locations accounted for 1855 (16.2%) cases, 601 (5.3%) cases were outer regional and 89 (0.8%) cases occurred in remote locations.

The mean (SD) age was 53.5 (23.1) years and 71.9% of patients were male. The most common mechanisms of injury were falls (44.3%), road trauma (37.6%) and blunt assault (5.9%). Penetrating injuries accounted for 3.6% of cases. Table one compares the demographic and clinical characteristics of rural/regional (combined inner, outer regional and remote injury locations) and metropolitan major trauma cases. With univariate analysis, rural/regional trauma was associated with younger age groups, and higher proportions of chest, abdomen spinal and lower limb severe injuries consistent with higher proportions of road trauma in the rural trauma population.

In-patient major trauma mortality trends

With respect to major trauma inpatient deaths 46.6% of deaths occurred in the first day, a further 30% occurred in the first week of admission, and 22.9% occurred after the second week of admission. The overall in-patient mortality rate for major trauma was 14.1% in 2009 and 14.5% in 2014 with no significant trend observed (p=0.66). There was no difference in overall in-patient mortality when comparing major trauma centre and non-major trauma admissions (14.0% versus 13.0% p=0.47). For those injured in metropolitan locations, in-patient mortality was 14.7% in 2009 and 16.1% in 2014 (Cochrane Armitage trend p=0.45). Major trauma in rural/regional locations was associated with a statistically significant decrease in in-hospital mortality from 12.1% in 2009 to 8.7% in 2014 (Cochrane Armitage trend p=0.004). When rural/regional location was further stratified, major trauma mortality in inner regional locations decreased from 12.7% in 2009 to 10.4% in 2014 (p=0.07), and for outer regional/remote locations the decrease was from 10.3% in 2009 to 4.0% in 2014 (p=0.005).

Figure 2 shows the risk adjusted OR for in-patient mortality between 2009 and 2014 stratified by location of injury demonstrating the trend in risk adjusted mortality associated with rural/regional and metropolitan locations of injury compared to reference year 2009. The adjusted OR for in-hospital mortality associated with rural/regional location of injury declined to 2013 (OR 0.5 95%CI 0.3, 0.8) and 2014 (OR 0.6 95%CI 0.4, 1.0) compared to 2009. In contrast there was no discernible trend in risk adjusted mortality associated with metropolitan location of injury.

Mode of arrival and inter-hospital transfer

Of the 2292 patients injured in a rural location and admitted to a major trauma centre there was no change in the proportion of major trauma patients arriving directly (not transferred in from another hospital) to a major trauma centre from a rural location between 2009 and 2014 (38.7% to 36.7% Cochrane Armitage trend p = 0.96) respectively. There was an increase in the proportion of these patients arriving at a major trauma centre by ambulance from a rural location (26.2% versus 60.6% p<0.001) and a decrease in the median time from injury to first trauma procedure from 276 (IQR 104-1420) minutes in 2010 to 95 (IQR 48-495) minutes in 2014 (p<0.001).

DISCUSSION

The present study demonstrates that although overall in-patient mortality after major trauma has remained steady between 2009 and 2014, crude mortality has decreased for those severely injured in rural and regional NSW over the same time period. There was a downward trend in risk adjusted mortality associated with rural location of injury which reached statistical significance in 2013. Comparison of crude in-patient mortality demonstrated that this trend was most marked for injury locations in outer regional and remote locations.

The findings could have resulted from a number of factors. Firstly, the implementation of trauma referral networks may have resulted in improved efficiency of transfers between rural facilities and major trauma centres. We demonstrated a decrease in the time to first trauma procedure for patients from rural areas since 2009. The NSW Ambulance Service trauma bypass (T1) protocol that was revised and implemented in 2008 allowed for an increase in transfer time between scene and arrival to the nearest designated trauma centre from 30 minutes to one hour[17]. In addition, the introduction of the Rapid Launch Trauma Co-ordinator function within the Ambulance Aero-medical Control Centre aimed to improve the early identification of major trauma incidents through monitoring of emergency triple zero calls to facilitate early activation of specialist pre-hospital resources. Both these factors may explain the steady increase in direct ambulance arrivals to Major Trauma Centres from rural locations between 2009 and 2014. This has occurred despite the proportion of inter-hospital transfers from rural and regional hospitals to Major Trauma Centre's remaining steady in the same period. It is unclear from the current literature whether direct or secondary transfer from a rural hospital or direct transportation to a major trauma centre is associated with improved survival. A 2011 systematic review of 36 observational studies found no such association although most were subject to potential referral bias (excluding deaths from referring hospitals)[18].

Secondly improved outcomes for severely injured rural patients may have resulted from improved clinical care at regional trauma centres and rural referral centres. A core mission of the NSW Institute for Trauma and Injury Management over the past decade has been the coordination and improved access to clinical expertise and education resources at rural and regional centres[12]. These included the employment of regional trauma nurse coordinators, resulting in improved education, case management, data collection and audit capabilities. A US study of 18 rural level 3 and 4 trauma centres demonstrated that a rural trauma education course alone was associated with improved time to transfer of severely injured patients[19].

Thirdly, the decrease in major trauma mortality in outer regional and remote locations also underscores the importance of road safety initiatives in preventing deaths and critical injuries. The reductions reported here mirror the reductions in road crash deaths by remoteness area between 2008 and 2012 with the road toll per 100,000 population decreasing by 11% in very remote locations compared to 0.7% in inner regional and 0.9% in metropolitan areas[20]. The National Road Safety Strategy highlights the need to prioritise improvements in high risk rural and urban roads, improved vehicle safety standards and improved safety for vulnerable road users[20]. Nevertheless rural road deaths continue to occur at two to three times the national average due to the longer travel distances, higher vehicle speed zones, increased likelihood of head-on collisions and vehicle rollovers compared to more urban locations[21]. This requires further attention and investment by all levels of government.

Of concern was the lack of overall improvement in metropolitan major trauma mortality in NSW since the initial report by Curtis et al[8] which reported a trend for improved mortality from 15.0% in 2003 to 12.9% in 2007 for patients with ISS>15. This appears to have increased slightly to around 15% and highlights the need for ongoing quality improvements in the major trauma system in NSW, including regionalisation of trauma centres[22] and models of care required to sustainably manage the growing proportion of elderly major trauma patients[23]. The overall mortality of patients with ISS>12 in 2013-14 (when all centres submitted data with ISS>12) was 11.1% in this study which was however, similar to the 11% reported by the Victorian population-based trauma registry in 2013-14[24]. It remains to be seen whether trends in risk adjusted mortality associated with rural/regional trauma relative to 2009. Although the downward trend was apparent in Figure 2, the decrease was only statistically significant in 2013. This may be due to the relatively small sample of patients in the rural/regional cohort, with narrower confidence limits if more rural and regional cases were included. Future analyses inclusive of years with complete data, including physiological data from rural/regional trauma centres is required to investigate to confirm these trends and perform further risk adjustment modelling consistent with other trauma registries[24].

Limitations

There are other acknowledged limitations to this study. Firstly, there were seven regional trauma centres that did not submit data to the state-wide trauma registry until after 2012 and therefore could not be included in this study. Deaths at the scene were also excluded which may have biased reported trends in rural trauma mortality. Secondly formal risk adjustment of in-patient mortality using physiologic parameters was impracticable as almost 30% of all cases in the trauma registry had no vital sign values entered. Risk adjustment of in-patient mortality is important to adjust for presumed differences in patient characteristics between various locations and facilities with respect to mechanism of injury, age and physiological parameters. The study however did use ICU admission as a proxy marker for physiological abnormality, but the risk adjustment models reported here would not be comparable to those reported by the Australian Trauma Registry and similar studies used to benchmark performance of trauma systems across different locations and facilities[25]. The period between 2009 and 2012 saw a transition from a collection of individual hospital based trauma registries to a uniform state-wide registry designed to streamline data collection, auditing and research across all designated trauma centres. Some of the issues around missing values could have been explained by this transition period.

Finally as the purpose of this study was to evaluate in-hospital mortality and overall trauma system performance and trauma centre care, we only analysed patients who survived to hospital presentation and excluded those who died at the scene or were declared dead on arrival. These numbers would be reflected in overall road toll statistics which also demonstrate declining mortality in NSW.[20] Coupling the results of the present study with declining rural road toll numbers would bias in favour of our hypothesis that overall rural trauma mortality has declined significantly since 2009, In conclusion, crude and risk adjusted in-patient mortality from major trauma has remained stable for those injured in metropolitan areas of New South Wales. The trend in risk adjusted mortality is encouraging but further analyses are required when data from other regional trauma centres in this state are available.

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Table 1 Baseline demographics, clinical characteristics and inhospital mortality of major trauma patients (Injury severity score >15) by location of injury, NSW Trauma Registry, 2009-2014. *Annual mortality based on yearly total deaths and major trauma cases

	Metropolitan NSW (n=8878)		**Rural/regional NSW (n=2545)**		***P* value**
	n	%	n	%	
Age (%)					<0.001
16-24 years	1191	13.4	473	18.6	
25-44 years	2108	23.7	735	28.9	
45-64 years	2091	23.6	678	26.7	
64-84 years	2441	27.5	565	22.2	
>84 years	1047	11.8	94	3.7	
Male (%)	6294	70.9	1920	75.4	
Mechanism (%)					<0.001
Road trauma	2994	33.7	1298	51.0	
Falls	4276	48.2	713	28.0	
Penetrating trauma	347	3.9	72	2.8	
Blunt assaults	527	5.9	150	5.9	
Burns	180	2.0	41	1.6	
Other	554	6.3	269	10.6	
Injury Severity Score					0.23
15-24	5119	57.7	1428	56.1	

25-49	3518	39.6	1036	40.7	
≥50	241	2.7	81	3.2	
Severe injury (AIS>2)					
Head	5128	57.8	1266	49.7	<0.001
Chest	3028	34.1	1080	42.4	<0.001
Abdomen	855	9.6	275	10.8	0.08
Spine/Vertebral column	997	11.2	413	16.2	<0.001
Upper limb	104	1.2	48	1.9	0.005
Lower limb	1342	15.1	496	19.5	<0.001
External	143	1.6	32	1.2	0.20
Mode of arrival to initial hospital (%)					<0.001
Ambulance	7310	87.3	1234	58.4	
Helicopter	547	6.5	692	32.8	
Fixed wing	6	0.1	47	2.2	
Private Vehicle	470	5.6	133	6.3	
Other	42	0.5	7	0.3	
In-patient mortality* (%)					
2009 (n=1790)	209	14.7	45	12.1	0.19
2010 (n=1749)	207	15.4	49	12.1	0.10
2011 (N=1808)	216	15.4	39	9.6	0.003
2012 (N=1895)	206	14.5	41	8.7	0.002
2013 (N=2062)	250	15.2	26	6.2	<0.001
2014 (N=2119)	266	16.1	41	8.7	<0.001

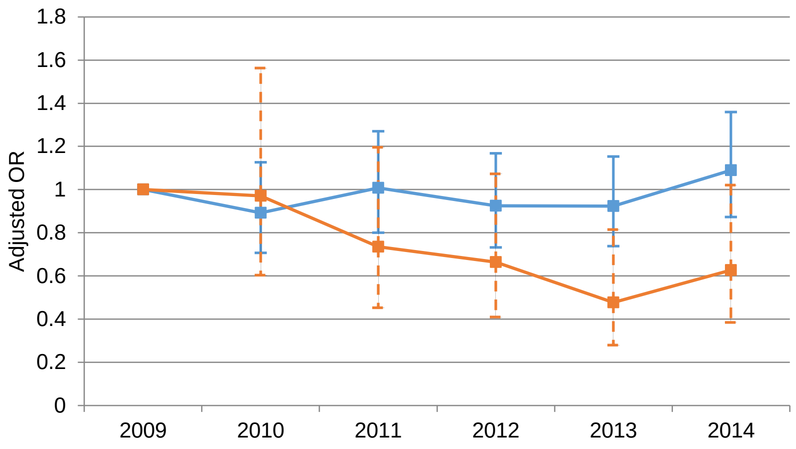

Figure 2 – Risk adjusted odds ratios (OR) for mortality trends for major trauma trends 2009-2014 in NSW stratified by location of injury (blue = metropolitan, red=rural/regional) using 2009 as reference year. Estimates and 95% confidence intervals compared against 2009 and not between rural/regional and metropolitan locations (ie Intersecting confidence bands have no relationship between separate models)

INTERVENTION AND OUTCOMES

SYNOPSIS

The following section details and evaluates the trauma quality improvement program initiated in 2007 in an effort to improve in-hospital mortality for severe injury and long term patient outcomes at Royal Prince Alfred Hospital. The section is divided into four chapters, an introduction which outlines the quality improvement program, a formal evaluation of trauma mortality pre and post implementation of this program using time series analysis and a cost effectiveness analysis to ascertain whether the improvements were associated with acceptable costs associated with improving the trauma service.

Finally, a description of long term patient outcomes associated with the trauma quality improvement program provides an insight into health status of patients three and six months after discharge from hospital. Although instituted as part of the quality improvement program, it also provides a useful baseline from which future improvement programs can be evaluated. The outcome measures used were identical to those used by the Victorian State Trauma Outcomes Registry and have been incorporated into specific post discharge clinical pathways for the management of post-traumatic stress disorders, post traumatic amnesia and wound management.

This section contains reprints of the following publications;

- Dinh MM, Bein KJ, Gabbe BJ, Byrne CM, Petchell J, Lo S, Ivers R. A trauma quality improvement programme associated with improved patient outcomes: 21 years of experience at an Australian Major Trauma Centre. Injury. 2014 May; 45(5):830-4. doi: 10.1016/j.injury.2013.11.005. Epub 2013 Nov 15.
- Dinh MM, Bein KJ, Hendrie D, Gabbe B, Byrne CM, Ivers R. Incremental cost-effectiveness of trauma service improvements for road trauma casualties: experience of an Australian major trauma centre. Aust Health Rev. 2015 Sep 14. doi: 10.1071/AH14205. [Epub ahead of print]
- Dinh MM, Cornwall K, Bein KJ, Gabbe BJ, Tomes BA, Ivers R. Health status and return to work in trauma patients at 3 and 6 months post-discharge: an Australian major trauma centre study. Eur J Trauma Emerg Surg. 2015 Aug 11. [Epub ahead of print]

CHAPTER TEN

TRAUMA SERVICE QUALITY IMPROVEMENT PROGRAM 2007-2010

The following outlines in detail the components of the quality improvement process initiated by the Department of Trauma Services at Royal Prince Alfred Hospital from 2007 to 2010. The key components were data collection, evidence based protocols, measurement of key performance indicators on all trauma patients and education and training. This represents a complete continuous quality improvement framework.

OBJECTIVE

The aim of the quality improvement was to improve in-hospital mortality for severely injured patients and assess health status of trauma patients who are discharged from hospital.

METHODS

The evaluation strategy for the quality improvement program can be broken into several key components

1. Data collection – pre and post intervention
2. Measurement parameters – key performance indicators
3. Intervention formulation – protocol formulation
4. Translation – through staff training and education
5. Determine effectiveness – Time series analysis of in-hospital mortality (Chapter 11), Cost effectiveness analysis (Chapter 12) and Follow up outcomes (Chapter 13)

DATA MANAGEMENT

Data management involved collection of clinical and hospital outcomes data on all trauma patients receiving a trauma team activation, regardless of patient disposition from the Emergency Department. Clinical notes from these patients were reviewed by trauma case managers and Clinical Nurse Consultants at the time of trauma tertiary survey within 24 hours of patient admission to the hospital or abstracted from Emergency Case notes on discharged patients. Cases reviewed using key performance indicators were entered into a trauma quality registry (see below), and reported on a weekly basis at trauma unit meetings and monthly hospital trauma committee meetings. Data was entered into a secure online trauma registry by trauma data managers and was externally audited for completeness on a quarterly basis by the NSW Institute of Trauma and Injury Management. Consenting patients were enrolled in a study investigating long term outcomes of patients after discharge from hospital. Trauma service clinical service roles and responsibilities for this program are outlined in further detail in the Appendix (Trauma Service Manual 2009)

JUSTIFICATION FOR USE OF MORTALITY OUTCOME

In hospital mortality for severe injury (ISS>15) was used as the main outcome measure for the study evaluation. Although only a crude measure of acute care function, its use was consistent with previous literature on trauma quality improvement programs (See Chapter 2) as an overall measure of effectiveness in the reduction of mortality in severely injured patients.

PROTOCOL IMPLEMENTATION

Trauma team activation protocol[1] – this was a set of criteria based on the existing American College of Surgeons Committee on Trauma that required the activation of the hospital trauma team response in the Emergency Department. Prior to this period, trauma teams were activated at the discretion of the triage nurse or Emergency Physician. Refer to appendix for full details of the protocol and its performance. The full trauma team consisted of Anaesthetics Registrar, General Surgical Registrar, Intensive Care Registrar, Emergency Consultant and Registrar, Radiographer.

Secondary "Supertriage"[2] – these constituted criteria for the mandatory involvement of both the Emergency Physician and Trauma Surgeon on call. These criteria were;

- Systolic blood pressure <90mmHg confirmed in the resuscitation bay
- Use of any blood products for a trauma patient
- Gunshot wound to the torso or neck
- Major disagreement within trauma team
- Three or more simultaneous full trauma activations occurring within the Emergency Department

Massive Transfusion protocol[3]

This protocol was activated when there is evidence of life threatening haemorrhage. The aim was to achieve balanced resuscitation of blood products and avoidance of coagulopathy. Blood products were delivered to the patient commencing with four units of pack cells and four units of fresh frozen plasma. Activation of the protocol initiated a process whereby blood bank thaws fresh frozen plasma.

“Code Crimson” protocol

The aim of code crimson was the transfer of any trauma patient with life threatening haemorrhage to the Operating Theatre within twenty minutes of code activation. Activation of the protocol notifies the Trauma Surgeon Anaesthetist and Operating Theatre Nurse in charge. There was simultaneous activation of the Massive Transfusion Protocol when Code Crimson protocol is activated.

Other policies implemented

Head injury assessment and management – this policy governed the assessment, imaging and initial management of mild moderate and severe head injury, based on current evidence based guidelines[4] promulgated by the Ministry of Health

Cervical Spine assessment and management – this policy governed the assessment, imaging and initial management of cervical spine, including the principle of cervical spine clearance based on Canadian C Spine rules[5]

Blunt chest trauma pathway – this guideline governs the initial, resuscitation assessment, monitoring and disposition pathways associated with blunt chest injury.

MEASUREMENT PARAMETERS

These key performance indicators define what the trauma department considered ideal processes of care and were assessed on every trauma patient regardless of injury severity. They were based the need to monitor compliance with above protocols, on peer review and existing State-wide trauma guidelines. Although the key performance indicators were formulated a number of years prior to the studies by Stelfox et al.[6] they were indeed found to be similar in dimension. The KPIs cover all relevant domains during the acute care period (Pre-hospital, triage, Emergency Department, Operating Theatre, Ward, Intensive Care Unit and outpatient care)

Indicator	Acute care domain	Indicator source	Audit filter
Scene time >20 minutes	Ambulance	State-wide KPI	Ambulance arrival to scene departure time
Trauma team activation*	Triage	RPA specific	Full trauma team activation for all major trauma patient (ISS>15, requiring Intensive Care or transfer to Operating Theatre)
Trauma team	Emergency	RPA specific	Presence of all team members
Airway intubation	Emergency	State-wide KPI	Intubation of severe head injury within 10 minutes of patient arrival
Code Crimson*	Emergency/Operating Theatre/Blood Bank	RPA specific	Transfer time < 20 minutes to operating theatre for all Code Crimson patient
Cervical Spine	Emergency	RPA specific	Assessment and clearance documented in clinical notes
Radiology Imaging*	Emergency	RPA specific	Trauma series X Rays (CXR and PXR) within 10 minutes of arrival
			Transfer to CT within 1 hour of patient arrival
Medical documentation	Emergency	RPA specific	Complete trauma form with ongoing management plan in medical notes
Mandatory notification of Consultant	Surgery	RPA specific	Notification of all patients meeting protocol criteria
Nursing documentation	Emergency	RPA specific	Vital sign documentation on arrival, temperature and
Fluid resuscitation*	Emergency	RPA specific	Fluid warmer for all patients receiving blood products. Blood products after two litres of crystalloid bolus
Definitive Care*	Surgery	State-wide KPI	Time to urgent laparotomy within 2 hours of injury scene time
	Surgery	State-wide KPI	Time to urgent craniotomy within 4 hours of injury scene time

	Surgery	State-wide KPI	Time to open reduction for open long bone fractures within 6 hours of injury time
Tertiary survey	Ward	State-wide KPI	Trauma reassessment within 48 hours of patient admission
Preventing complications	ICU	State-wide KPI	Unexpected readmission to Intensive Care Unit
	Ward		Undiagnosed injury within 48 hours of admission
	Ward	State-wide KPI	Nosocomial infection
	Ward	State-wide KPI	Venous thromboembolism prophylaxis for appropriate patients
Long term outcomes*	Recovery	RPA specific	Unplanned readmission within 7 days of discharge Admission for another major injury Health status at 3 and 6 months Post-traumatic stress disorder

Table 1 – Key performance indicators used in the Royal Prince Alfred Hospital Trauma Quality Improvement program *Audits published previously as separate reports prior to thesis (see Appendices)

QUALITY REVIEW MEEETINGS

- Weekly trauma unit meeting – all trauma patients reviewed and clinical issues and performance indicators discussed. Follow up of issues range from personal correspondence, report to hospital incident management system (IMS) and policy review
- Monthly hospital trauma committee meeting – peer reviewed morbidity and mortality meeting with ICU, Anaesthetics, Radiology, ED, Ambulance representation
- Weekly Trauma Radiology review meeting – all imaging for trauma patients reviewed.

EDUCATION AND TRAINING

Education

Trauma education and training underpinned the translation strategy of turning of new policies and protocols into clinical practice. Monthly trauma education sessions and trauma team training exercises focused on the execution of these policies and education and remediation of any ongoing clinical issues identified during case reviews. An e-learning platform was implemented to assist with the implementation of education modules for Code Crimson and other trauma policies[7]. Knowledge was continually audited using this Web 2.0 platform to ensure compliance with protocols. Clinical meetings are outlined below

- Monthly trauma grand rounds with case presentations and discussion around trauma policies – mandatory attendance of ED medical and nursing staff
- Bimonthly trauma hospital wide multidisciplinary meetings
- Bimonthly trauma simulation training seminar – four hours with attendance from Anaesthetics Intensive Care and General Surgery Registrars with case discussion and simulation based training
- Relevant policies and processes of care uploaded onto trauma intranet website and smart phone application, available on Android and iTunes.

POTENTIAL BENEFITS OF APPROACH

The principal advantages of this trauma were the surveillance and early identification of clinical issues relating to compliance with key performance indicators in all trauma patients, not just severely injured ones. In most instances variations in care can be justified, but clinical variation that cannot be justified are reported to the hospital trauma committee and remedial action taken in the form of policy review, education and simulation training. The recording of clinical issues in a registry allows data to be aggregated, audited on a regular basis and reported at various committees.. Data on all trauma patients regardless of injury severity provides a less biased estimate of the burden of particular injury types and syndromes to inform injury prevention strategies and policies[8,9].

POTENTIAL LIMITATIONS

Even though the following papers provide strong evidence of the clinical and cost effectiveness of the trauma quality improvement program, an important caveat is that this reflects the experience of a single trauma centre. This is a relatively small volume trauma centre with around 1000 trauma activations per annum, with only 2% of penetrating trauma. Clinical indicators such as these whilst common to many other trauma centres, may not be applicable to higher volume trauma centres or those in less developed trauma systems. Although attempts were made to account for all trauma related enhancements, improvements in mortality could be attributable to unmeasured confounders such as improved resourcing and training of Radiology and improvements made in prehospital care, including Retrieval Medicine care.

COMPLIANCE WITH KEY PERFORMANCE INDICATORS

Formal audits were performed on several key performance indicators during the quality improvement program. These included knowledge amongst clinical staff of code crimson, trauma team activation criteria which was benchmarked against American College of Surgeons standards for undertriage and overtriage, head injury definitive care, and radiology usage in trauma resuscitations. These were all performed prior to the author's candidature in the doctoral program[10,11, 12].

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CHAPTER ELEVEN

A trauma quality improvement program associated with improved patient outcomes: 21 years of experience at an Australian Major Trauma Centre.

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ABSTRACT

Introduction - Quality improvement programs are an important part of care delivery in trauma centres. The objective was to describe the effect of a comprehensive quality improvement program on long term patient outcome trends at a low volume major trauma centre in Australia

Methods - All patients aged 14 years and over with major trauma (Injury Severity Score >15) admitted to a single inner city major trauma centre between 1992 and 2012 were studied. The outcomes of interest were in-hospital mortality and transfer to rehabilitation. Time series analysis using integer valued autoregressive Poisson models was used to determine the reduction in adjusted monthly count data associated with the intervention period (2007-2012). Risk adjusted odds ratios for mortality over three yearly intervals was also obtained using multivariate logistic regression. Crude and risk adjusted mortality was compared before and after the implementation period.

Results - 3856 patients were analysed. Crude in-hospital mortality fell from 16% to 10% after implementation ($p<0.001$). The intervention period was associated with a 25% decrease in monthly mortality counts. Risk adjusted mortality remained stable from 1992 through to 2006 and did not fall until the intervention period. Crude and risk adjusted transfer to in-patient rehabilitation after major trauma also declined during the intervention period.

Conclusion - In this low volume major trauma centre, the implementation of a comprehensive quality improvement program was associated with a reduction in crude and risk adjusted mortality and risk adjusted discharge to rehabilitation in severely injured patients.

Keywords – trauma, mortality, quality improvement

INTRODUCTION

Substantial evidence currently exists supporting the relationship between adequately resourced trauma centres operating within regionalised trauma systems and improved mortality in severely injured patients [1,2]. A study in Victoria Australia, demonstrated a decrease in risk adjusted patient mortality over five years after the implementation of a state-wide trauma system [3]. A pre and post implementation study across four years in the Netherlands also demonstrated a 16% reduction in risk adjusted in-patient mortality[4]. There are few studies that examine long term trends in mortality. An inclusive state-wide trauma system in Delaware was associated with a 25% absolute reduction in crude mortality for severely injured patients (Injury Severity Score>24) over 10 years[5]. Investigators at the R Adams Cowley Shock trauma centre also studied trends in mortality over ten years between 1997-2008 and found a small decrease in mortality in patients with an Injury Severity Score between 17 and 24 [6].

Whilst the emphasis in trauma care evaluation has focused on systems across regions, few studies have investigated the impact of quality improvement processes within individual trauma centres over the long term. Variations in outcomes have been demonstrated across many trauma centres of similar capabilities and may reflect differing approaches to quality improvement [7]. A study by Sarkar et al [8] from Michigan USA evaluated the effect of a comprehensive performance improvement program and demonstrated a 12% reduction in trauma mortality (ISS>24) over five years at a Level 1 trauma centre. A recent study across four countries identified differences in quality improvement processes used in low volume compared to high volume trauma centres [9]. Low patient volume trauma centres were associated with higher use of benchmarks associated with triage, patient flow and effectiveness of care. Higher patient volume centres reported higher use of benchmarks related to medical errors and adverse events.

It is unclear whether such quality improvement programs can result in improved patient outcomes that are achievable and sustainable in the Australian context. A State-wide trauma system in New South Wales, Australia with a population of over 7 million people, was established in 1992 [10]. There are currently seven designated adult Major Trauma Centres, six of whom are located in metropolitan Sydney. As a consequence of this concentration of trauma centres, most of these would be considered low volume trauma centres under current international standards. The objective of this study was to describe the effect of a comprehensive quality improvement program on long term patient outcome trends at one of these Major Trauma Centres. Information gained may help confirm the importance, effectiveness and sustainability of rigorous quality assurance processes at trauma centres, particularly those within trauma systems where lower patient volume trauma centres predominate.

METHODS

Design – Single centre trauma registry study over 21 years

Setting – The study was conducted at an inner City Major Trauma Centre in Sydney, Australia's largest city. There are currently around 200 major trauma presentations (ISS>15) per year. Although a State-wide trauma system was implemented in 1992, there was only one part time trauma director prior to 2006 at this institution, and no structured trauma education program or quality improvement processes. In 2007 a comprehensive trauma quality improvement program was initiated after the appointment of three trauma Co-Directors – an Emergency Physician, Colorectal Surgeon and Orthopaedic Surgeon. The program consisted of implementation of a tiered trauma team activation protocol, mandatory notification criteria for Trauma Surgeon and Emergency Physician on-call, a structured trauma education and case review program, massive transfusion protocol and implementation of a number of quality benchmarks consistent with those described in previous studies (9). These formed the basis of trauma case reviews conducted by trauma clinical nurse consultants on every admitted trauma patient and reported at monthly committee meetings. In 2009 a hospital wide 'Code Crimson' for expedited surgical management of haemorrhage in trauma was initiated. All patients requiring in-patient rehabilitation were transferred to external rehabilitation facilities, including brain injury units outside this institution and there have been no major changes to referral patterns over the past 20 years.

The trauma registry has prospectively collected pre-hospital, in-hospital and discharge destination information about all trauma admissions to this institution by the same trauma data manager since 1991.

Study population – All adult patients (age ≥14years) with major trauma (ISS>15) presenting to this hospital between January 1992 and December 2012 were included. Cases were excluded if information on patient outcomes were missing.

Data collected - Data collected for this study included demographics (age, sex), mechanism of injury, mode of arrival, vital signs on arrival to the emergency department, injuries and injury severity score and patient outcomes. Injuries and injured body regions were classified using the Abbreviated Injury Scale(11) (AIS) 1990 and 1998 versions prior to 2009 and 2005 version thereafter. Severe head injuries were defined as any head injury with an AIS severity score of three or more. Period of presentation was divided into three yearly intervals to enable long term risk adjusted trends to be presented.

Outcomes - The primary outcome was in-hospital mortality. All deaths in the Emergency Department were included. The secondary outcome was transfer to in-patient rehabilitation facilities in patients surviving to hospital discharge, as a proxy marker of functional impairment requiring ongoing medical care.

Statistical analysis

A univariate analysis to compare before and after periods with respect to patient characteristics and outcomes was performed. The effects of the intervention period on monthly in-hospital mortality counts was analysed using integer valued autoregressive Poisson models, adjusting for age (age ≥ 65 years, seasonality (warmer months from October to March)) and any underlying linear trend. The distribution of monthly deaths was assumed to follow a Poisson distribution. This modelling technique has been shown to be superior to other time series methods such as autoregressive integrated moving average models where counts are relatively low[12]. Risk adjusted mortality and rehabilitation trends (in survivors to hospital discharge) were determined using multivariate logistic regression with data aggregated into three yearly intervals, compared to reference years (1992-94) and a-priori defined variables based on a previous studies[3,13] and known to vary across time at this institution[14]. Binary variables were severe head injury (Head Abbreviated Injury Scale score ≥ 3), transfer from another health facility, hypotension (systolic blood pressure <90mmHg on arrival to emergency department) and Intensive Care Unit admission. Age, ISS and mechanism of injury were categorised into clinically relevant categories as shown in table 1. Analyses were conducted using SAS 9.3 (SAS Institute Cary NC).

Ethics

Approval was obtained from the Sydney Local Health District Research Ethics Committee (RPAH zone).

RESULTS

A total of 3873 cases were identified of which 17 had missing outcome data, leaving 3856 cases analysed. The mean age was 48 years (SD 22) and 74% were male. The number of major trauma admissions each year has increased slowly from around 150 patients per year prior to year 2000 to around 200 patients per year after 2001.The overall mortality was 14% and of the survivors to hospital discharge, 34% were transferred to rehabilitation facilities.

A comparison of baseline characteristics before (1992-2006) and after (2007-2012) the implementation of the quality improvement program is shown in table 1. Patients in the "after" group were associated with older age, increased proportion of falls and severe spinal or vertebral column injuries, similar proportion of severe head injuries and reduced admissions to ICU. Crude in-hospital mortality decreased from 16% to 10% ($p<0.001$) as did transfers to in-patient rehabilitation (38% versus 28% $p<0.001$).

Time series analyses (monthly counts)

After adjusting for age and seasonality, the coefficient value of the intervention period (2007-2012) was -0.29 (95%CI -5.64, -0.01) which equates to a 25% reduction in monthly death counts associated with the onset of the intervention period after adjusting for underlying trends (Table 2). Figure 1 graphically presents the trend in adjusted log monthly mortality counts and demonstrates the decrease in mortality since 2007.

Risk adjusted outcomes (three year intervals)

Risk adjusted mortality (Table 3) remained steady compared to the reference period (1992-94) and did not reduce below the reference period until 2007 when the risk adjusted odds ratio fell from 1.10 (95%CI 0.73, 1.66) in 2004-06 to 0.72 (95%CI 0.47, 1.10) in 2007-09 and decreased further thereafter. Odds ratios for transfer to in-patient rehabilitation also fell significantly between 2007-2009 (OR 0.69 95%CI 0.53, 0.91 p=0.01) and 2010-12 (OR 0.51 95%CI 0.39,0.69 p<0.001) after adjusting for age, severe head injury, lower limb injury and ISS.

DISCUSSION

The present study was undertaken to describe long term trends in patient outcomes and the impact of quality improvement processes implemented since 2007 at an Australian major trauma centre. Using a time series analysis approach, the period after 2006 was associated with a 25% reduction in mortality after major trauma after adjusting for underlying trends. Using risk adjustment techniques, the period after 2006 was associated with a statistically significant reduction in risk adjusted mortality. This improvement was paralleled by a decrease in risk adjusted transfer for in-patient rehabilitation after major trauma.

The reduction in crude mortality to around 10% over the past six years compares favourably to the overall major trauma mortality in New South Wales which has remained around 13-14% throughout the last decade, as well as the most recent mortality data available from Victoria [15,16].

Few studies have explored the association between the presence of trauma quality improvement systems and reduced risk adjusted mortality[13]. A cross sectional survey of 59 trauma hospitals in Quebec Canada found that the presence of a quality improvement program was the strongest predictor of survival after risk adjustment [17]. A recent study by Wong et al. from a larger trauma service in NSW demonstrated a 3% reduction over 10 years in crude mortality since the introduction of a specialist trauma service with similar clinical care protocols[18]. This study was unable to adjust mortality for abnormal physiology, intensive care use or underlying time trends.

The findings of the present study are timely given the recent establishment of the Australian Quality Improvement Program (AustQIP), a collaboration of 26 major trauma centres including this institution [19]. The aim of AustQIP is to enable an integrated and coordinated approach to quality systems and patient safety initiatives across all trauma centres in Australia.

The changes described here were achieved at a low volume trauma centre which has not employed a full time trauma surgeon since 1998. The trauma surgeon on call roster at this institution was staffed by surgeons from multiple subspecialties. Although some studies suggest that full time trauma surgeons are associated with better outcomes for severely injured patients [20], other studies point out that the relationship is more complex, and that characteristics of the trauma system at any given hospital may play a more important role in determining outcomes [21].

The strengths of the present study include the length of time studied, the use of time series analysis to adjust for underlying long term trends, and the use of risk adjustment for in-hospital mortality and discharge to rehabilitation. The advantages of reporting long term trends and time series analyses include the ability to demonstrate sustained improvements in patient outcomes and adjusting for existing trends before the introduction of system changes. It therefore reduces the risk of erroneously attributing observed changes to an intervention rather than an underlying trend or random variation over short periods of time. Few studies involving major trauma have reported long term trends in rehabilitation use, even though rehabilitation is a key component of the trauma system and may be considered a marker of severe ongoing disability that may be mitigated by improved early management for trauma [22].

There were a number of acknowledged limitations to the study. Monthly mortality counts were low and this may affect the robustness of our conclusions. The present study has accounted for this by using appropriate time series modelling. Several important changes over the past decade may have partly explained the observed trends that were not accounted for in the study. These include improved care of patients in Intensive Care Units, through better ventilation strategies and management of sepsis and multi-organ failure [23,24], increased staffing with Emergency Physicians, damage control surgery and improved access to diagnostic and interventional Radiology. In addition several changes to road traffic laws in New South Wales over the past 20 years, such as reduced urban speed limits and drink driving laws have resulted in reduced road fatalities [25], resulting in more patients with severe injuries surviving to hospital admission and ultimately discharge.

Although performance indicators were regularly audited, we have not presented trends in protocol compliance here, given the number and complexity of indicators involved. We were not able to compare our performance with contemporaneous trends across New South Wales as data after 2009 were not available at time of writing. Finally this was a single centre study, and some of the quality improvement processes described here and the improved outcomes associated with them may not be transferrable to other institutions.

In conclusion, in this single centre study, the introduction of a comprehensive quality improvement program was associated with a reduction in long term crude and risk adjusted mortality and discharge to rehabilitation in severely injured patients. The results provide further supportive evidence for the role quality improvement programs in trauma centres, particularly in the context of low volume trauma centres operating within inclusive trauma systems. Maintaining and improving on observed trends describe here will be one of the main challenges going forward, particularly in the context of an ageing population, and the anticipated revisions to the trauma system in New South Wales.

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TABLES AND FIGURES

Table 1 - Comparison of baseline characteristics before (1992-2006) and after (2006-2012) implementation of quality improvement program IQR= interquartile range, transfer=arrival from another health facility, rehabilitation=transfer to in-patient rehabilitation services (excluding deaths), AIS=Abbreviated Injury Scale, SBP=systolic blood pressure. Penetrating

mechanism includes gun injuries, stabbings and self-inflicted penetrating injuries

	1992-2006 N=2605	2007-2012 N=1251	P value
Age (median, IQR)	42 (27,64)	51 (32,72)	<0.001
Age 14-24yrs (%)	508 (20)	171 (14)	
Age 25-44 yrs (%)	871 (33)	347 (28)	
Age 45-64 yrs (%)	583 (22)	313 (25)	
Age 65-84 yrs (%)	540 (21)	326 (26)	
Age >84 yrs (%)	103 (4)	94 (8)	<0.001
Male (%)	1953 (75)	914 (73)	0.20
Interhospital transfer (%)	739 (28)	238(19)	0.001
ICU (%)	1728 (66)	603 (48)	0.001
SBP<90mmHg (%)	206 (8)	87 (7)	0.29
ISS			
16-24	1361 (52)	758 (61)	
25-49	1101 (42)	455 (36)	
>50	143 (5)	38 (3)	<0.001
Mechanism			<0.001
Falls	889 (34)	596 (48)	
Road trauma	1004 (39)	380 (30)	
Blunt assault	282(11)	109(9)	
Penetrating	196 (8)	62 (5)	
Other	234 (9)	104 (8)	
Head (AIS≥3) (%)	1819 (70)	857 (69)	0.40
Spine/Vertebral column (AIS≥3) (%)	174(7)	131(10)	0.01
Chest (AIS≥3) (%)	818 (31)	405 (32)	0.54

Abdomen (AIS≥3) (%)	398 (15)	129 (10)	<0.001
Upper limb (%)	642 (25)	353 (28)	0.02
Lower limb (%)	674 (26)	335 (27)	0.55
In-hospital mortality (%)	420 (16)	128 (10)	<0.001
Inpatient rehabilitation (%)	820 (38)	318 (28)	<0.001
Length of stay (days, median IQR)	9(4,19)	8 (4,19)	0.32

Table 2 – Integer valued autoregressive (AR) Poisson model for monthly deaths from major trauma, SE= standard error, AR(1) = autoregressive term with 1 month lag. Root mean square error = 0.44, Intervention period = 2007-2012

Variable	Coefficient	SE	95%CI	P value
Constant	-1.55	0.43	-2.39, -0.70	<0.001

Log_e(monthly total major trauma)	0.89	0.17	0.56, 1.22	<0.001
Monthly trend	-0.020	0.00088	-.0037, -0.0002	0.029
Seasonality (October-March)	0.043	0.083	-0.20, 0.12	0.61
Age(≥65yrs)	0.043	0.021	0.0038, 0.084	0.048
Intervention period	-0.29	0.14	-0.56, -0.01	0.042
AR(1)	0.028	0.06	-0.091, 0.15	0.64

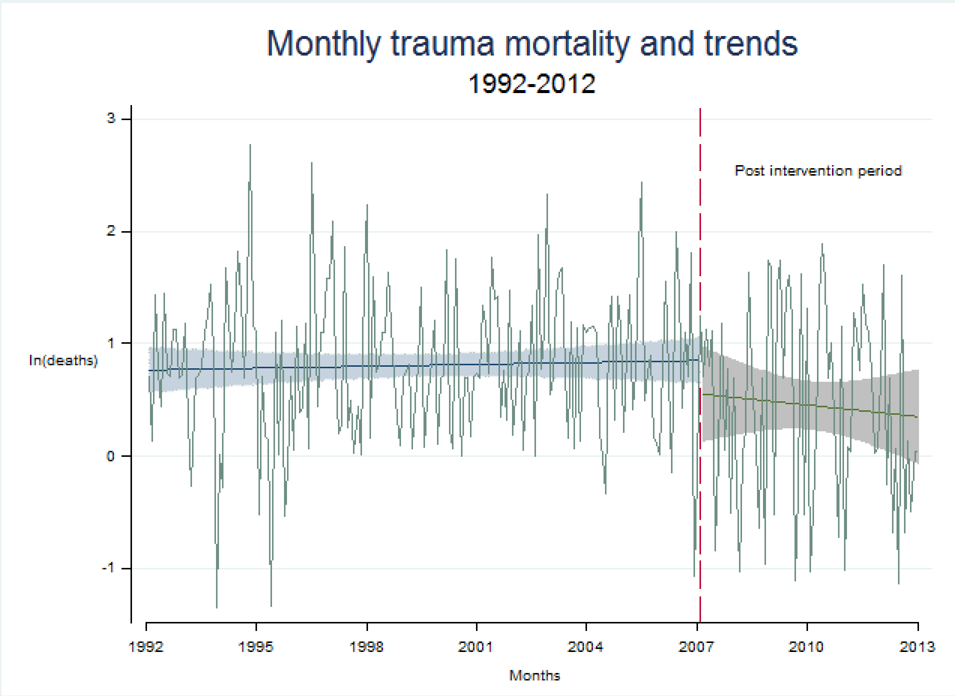
Table 3 – Risk adjusted odds ratios (OR) for mortality including all variables used for adjustment, AIS=Abbreviated Injury Scale, SBP=systolic blood pressure, ISS=Injury Severity Score, Penetrating mechanism includes gun injuries, stabbings and self inflicted penetrating injuries

	OR	**95%CI**	**p**

1992-94	[reference]	-	-
1995-97	1.20	0.78, 1.83	0.40
1998-00	1.12	0.73, 1.71	0.59
2001-03	1.14	0.76, 1.71	0.53
2004-06	1.11	0.73, 1.66	0.62
2007-09	0.72	0.47, 1.10	0.13
2010-12	0.63	0.40, 0.98	0.04
Age14-24	[reference]	-	-
25-44	0.86	0.60, 1.25	0.42
45-64	1.46	0.96, 2.07	0.07
65-84	2.46	1.69, 3.59	<0.001
>85years	4.71	2.81, 7.91	<0.001
SBP<90mmHg	7.64	5.37, 10.85	<0.001
ISS15-24	[reference]	-	-
ISS 25-49	13.44	9.76, 18.48	<0.001
ISS >50	72.62	44.25, 119.20	<0.001
Mechanism			
Other	[reference]	-	-
Assault	0.57	0.33,0.97	0.04
Road trauma	0.72	0.48, 1.08	0.11
Fall	0.46	0.30, 0.70	0.003
Penetrating	1.08	0.60,1.93	0.80
Head (AIS≥3)	2.52	1.84, 3.46	<0.001
Transfer	0.72	0.55, 0.93	0.01
ICU	0.94	0.92, 0.96	<0.001

Figure Legend

Figure 1 - Adjusted monthly mortality (log_e[death]) counts using autoregressive (AR1) Poisson modelling. Fitted linear regression lines before and after intervention (2007) with 95% confidence interval (shaded areas)



CHAPTER TWELVE

Incremental cost-effectiveness of trauma service improvements for road trauma casualties: experience of an Australian major trauma centre

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ABSTRACT

Objective

The objective of this study was to estimate the cost effectiveness of trauma service funding enhancements at an inner city Major Trauma centre.

Methods

This was a cost effectiveness analysis using retrospective trauma registry data of all major trauma patients (Injury Severity Score >15) presenting after road trauma between 2001 and 2012. The primary outcome was cost per life year gained associated with the intervention period (2007-2012) compared with the pre-intervention period (2001-2006). Incremental costs were represented by all trauma-related funding enhancements undertaken between 2007 and 2010. Risk adjustment for years of life lost was conducted using zero inflated negative binomial regression modelling. All costs were expressed in 2012 Australian dollar values.

Results

A total of 876 patients were identified during the study period. The incremental cost of trauma enhancements between 2007 and 2012 totalled $7.91 million, of which $2.86 million (36%) was attributable to road trauma patients. After adjustment for important co-variates the odds of in-hospital mortality reduced by around one half (adjusted OR 0.48, 95% CI 0.27, 0.82 p=0.01). The incremental cost-effectiveness ratio was A$7,600 per life year gained (95% CI A$5524, $19333).

Conclusion

Trauma service funding enhancements that enabled a quality improvement program at a single Major Trauma Centre were found to be cost effective based on current international and Australian standards.

KEY QUESTION SUMMARY

What is known about this topic?

Trauma quality improvement programs have been implemented across most designated trauma hospitals in an effort to improve hospital care processes and outcomes for injured patients. These involve a combination of education and training, the use of audit and key performance indicators.

What does this paper add?

A trauma quality improvement program initiated at this trauma hospital was found to be cost effective with respect to years of life saved in road trauma patients over 12 years.

What are the implications for practitioners?

These results suggest that adequate resourcing of trauma centres to enable quality improvement programs may be a cost effective measure to reduce in-hospital mortality following road trauma.

INTRODUCTION

Trauma quality improvement programs involve the coordinated, systematic and sustained endeavour to monitor and improve aspects of trauma care delivery [1-3]. By identifying and addressing deficiencies in care in hospitals, the primary goal of the trauma quality improvement program is to improve patient outcomes after injury. A number of studies have documented improvements in process of care and patient mortality associated with the implementation of hospital based trauma quality improvement programs, most often in conjunction with the implementation of regionalised trauma systems [4-10].

Although the effectiveness of trauma systems of care and quality improvement programs has been studied extensively, there are few studies examining the cost effectiveness of such interventions. There is a growing need to demonstrate value for money associated with trauma system improvements, given the current climate of rising health care costs and the perception that trauma care is expensive [11]. Cost effectiveness analysis provides a metric that informs policy makers about which programs and interventions yield the highest health benefit for a given amount of health spending.

The National Study on Costs and Outcomes of Trauma in the US measured health care related costs and found the cost effectiveness of trauma centre care compared to non trauma centre care to be around $36,000 per quality adjusted life year gained[11]. DiRusso et al[6] demonstrated a significant reduction in mortality after changes to their trauma program undertaken as a result of a trauma centre verification process. Estimated cost savings of around $4,000 per patient were demonstrated associated with reduced length of stay. No published studies to date have examined the cost effectiveness of trauma quality improvement programs in Australia.

New South Wales is the most populous state in Australia, and a state-wide trauma system was implemented in 1992 [13]. Over the past decade, a series of funding enhancements were appropriated to major trauma centres in NSW to ensure adequate medical and nursing expertise in trauma and facilitate hospital based trauma quality improvement programs [13]. We sought to estimate the cost effectiveness of these trauma enhancements at one major trauma centre specifically. Such information facilitate decisions regarding funding and resource allocation in the context of injury management.

METHODS

Design – A retrospective pre and post intervention cost effectiveness analysis at the hospital provider level, conducted at a single major trauma centre in New South Wales, Australia

Setting and trauma service intervention – The trauma centre is located in the inner city area in Sydney and treats approximately 3000 injury related admissions per annum, of which around 220 are classified as major trauma [Injury Severity Score (ISS) greater than 15, calculated using the 2005 version of the Abbreviated Injury Scale] [14]. The hospital trauma registry has routinely collected complete clinical information on all trauma related inpatient admissions since 1992. Prior to 2007, the trauma service consisted of a part time (0.5 full time equivalent, FTE) Trauma Director, a full time Trauma Clinical Nurse Consultant and a data manager. Between 2007 and 2010 a series of funding enhancements resulted in the employment of an additional 0.5 FTE Trauma Director primarily to provide clinical governance and leadership, an additional FTE Trauma Clinical Nurse Consultant and an FTE Trauma Case Manager. This enabled a number of improvements to the trauma service to occur which were not present prior to 2007, namely:

1. Collection of clinical data on all trauma patients, including those that were discharged directly from the emergency department, where previously only data on in-patient admissions were collected.
2. Establishment of a validated hospital wide tiered trauma team activation protocol[16]. Trauma team protocols also included an assessment tool and escalation policy for unstable patients and a “Code Crimson” integrated policy for patients requiring urgent haemorrhage control [16]. This involved the simultaneous mobilisation of both operating theatre staff and massive transfusion protocols. These protocols were not present prior to 2007.
3. Trauma key performance indicators including time to imaging studies and definitive care benchmarks that were used as audit filters by trauma nurses who reviewed all patients requiring trauma team activation;
4. Weekly patient review meetings where audit filters were reviewed for each trauma patient requiring trauma team activation irrespective of admission status.

5. Two-monthly trauma team training courses using high fidelity simulation facilities instituted in 2009 where important protocols and teamwork were taught and practiced.

Patient population – Patient data from the hospital trauma registry was included for adult (aged 15 years or over) major trauma patients (Injury Severity Score >15) presenting between January 2001 and December 2012, who had been admitted after a road trauma mechanism of injury. Road trauma was defined if the injured person was the occupant of a motor vehicle (car, truck, bus, and motor-bike), pedestrian or cyclist. Injury Severity Scores were calculated using the 2005 version of the Abbreviated Injury Scale[14], with scores prior to 2005 recalculated using the same version to ensure consistency.

Primary study measure – The incremental cost effectiveness ratio was estimated from a hospital provider perspective using cost per life year gained associated with the intervention compared to the pre-intervention period (see effectiveness section below).

Costs – Incremental costs were represented by all trauma related funding enhancements undertaken between 2007 and 2010. These included salaries and wages for additional staffing as outlined above, staffing for an additional Intensive Care Unit bed commissioned in 2010 for trauma, and staffing for an additional Emergency Department Resuscitation bed. The cost of a Trauma Orthopaedics Fellow employed in 2010 was also included. Total cost of the trauma centre improvements were allocated to road trauma patients based on their percentage share of all trauma patients (36%). Unit salary costs were obtained directly from the hospital. Therefore these costs comprised only additional staffing costs and cost savings were not considered in the study.

Effectiveness – Patient administrative data for trauma centre patients were obtained from the hospital. Records included information relating to admission date, length of stay, demographic characteristics, body region of injury, nature of injury, mechanism of injury, injury severity and survival [19]. Effectiveness was measured by comparing years of life lost (YLL) for each death for the pre-intervention period (2001-2006) and the post-intervention period (2007-2012), with YLL calculated using 2009-2011

Australian life tables [20]. The outcome measure of life years gained was the difference in YLL in the pre- and post-intervention periods.

Base year and discounting –The base year for the analysis was 2012. Costs and outcomes were discounted at an annual rate of 5% as recommended in guidelines for preparing submissions to the Pharmaceutical Benefits Advisory Committee [21].

Statistical analysis – Univariate comparison of demographic and injury-related characteristics and hospital episode of care for the pre and post-intervention periods was performed using descriptive statistics. Zero-inflated negative binomial regression was used for modelling YLL to account for excess zeroes in the outcome variable and over-dispersion. Risk adjustment modelling variables were based on those used by the American College of Surgeons Trauma Quality Improvement Program such as age, injury severity, intensive care unit admission, severe head injury and the presence of hypotension (systolic blood pressure < 90mmHg) but did not include co-morbidities [3]. All analyses were conducted using SAS 9.3 (SAS Institute Cary NC USA). Model discrimination and calibration were reported using the Area under the Receiver Operator Characteristic curve and the Hosmer-Lemeshow test statistic, respectively.

Sensitivity analysis: To test whether the results of the base-case analysis were dependent on the discount rate and the estimate of the reduction in YLL derived in this study, a sensitivity analysis was conducted by varying these two parameters over a range considered plausible. For YLL, the 95% confidence intervals (CIs) of the odds for dying post-intervention compared with pre-intervention were used to calculate 95% CIs of the number of life years gained at each discount rate. The annual discount rate was varied from 0% to 8%.

Ethics – Data retrieval was approved by the Ethics Review Committee of the Sydney Local Health District.

RESULTS

A total of 876 patients were identified during the study period. The median age was 39 years (IQR 25, 58) and 74% were male. Motor-vehicle (car) incidents comprised 34%, motorcyclists 16%, pedestrians 33% and cyclists 6% of the study population. Other mechanisms (bus or other motorised vehicle) comprised the remaining 11% of the population. There were 460 patients in the pre-intervention and 416 patients in the post-intervention group. Demographic and clinical characteristics of the study groups are compared in Table 1. The most notable differences were a significant increase in the proportion of cyclists and motorcyclists in the post-intervention period as well as fewer ICU admissions.

Costs -The incremental cost of trauma enhancements between 2007 and 2012 totalled $7.91 million, of which $2.85 million (36%) was attributable to road trauma patients.

Effectiveness

Unadjusted in-hospital mortality reduced from 16% in the pre-intervention group to 10% in the post intervention group, representing a 38% relative reduction (OR 0.58, 95% CI 0.39, 0.89 p=0.01). After adjustment for age, sex, mechanism of injury, hypotension (SBP<90mmHg), severe head injury, intensive care unit admission and inter-hospital transfer, the finding remained significant (adjusted OR 0.48, 95% CI 0.27, 0.82 p=0.01) (Table 2).

There was a significant reduction in mean years of life lost per patient in the post intervention period compared to pre-intervention period (2.4 years per patient 95% CI 1.8, 2.9) versus 1.5 years per patient (95 %CI 1.1, 2.0) p=0.003). Using the post intervention sample size as the reference, there were 374 years of life gained in the post-intervention group compared to pre-intervention assuming a 5% discount rate per annum.

Incremental cost-effectiveness ratio

The incremental cost-effectiveness ratio was A$7613 (95% CI 5524, 19333) per life year gained (Table 3).

Sensitivity analysis

Under the different discount rates adopted, the incremental cost of implementing the trauma improvement program varied from A$2.272 million for an annual discount rate of 8% to A$3.630 million with no discounting (Table 4). Incremental effectiveness varied from 250 life years gained (95% CI 99, 346) at an 8% discount rate to 915 life years gained (95% CI 362, 1266) with no discounting. Thus the incremental cost-effectiveness for the best case scenario was A$3967 (95% CI 2867, 10027) per life year gained and for the worst case scenario was A$9090 (95% CI 6600, 23068) per life year gained.

DISCUSSION

The present study reports on a quality improvement program, similar to the original framework (structure, process and outcome) described by Donabedian over 40 years ago [22]. Structural changes included additional staffing and increased resuscitation bay and intensive care unit capacity. Process changes were exemplified by trauma team protocols, trauma team training and key performance indicators. Outcomes reported in this study were in-hospital mortality and years of life saved. The findings of the present study demonstrate a 50% reduction in adjusted odds of mortality associated with trauma service enhancements and a quality improvement program initiated in 2007. The mortality reduction remained significant after adjustment for differences in age and ISS between the two study groups. The cost effectiveness of the trauma service enhancements was estimated to be around A$7600 for each year of life gained between the two study periods.

A number of injury prevention strategies have been evaluated with cost effectiveness analyses using mathematical modelling and available evidence [23]. In general primary prevention measures were found to be the most cost effective, but were dependent on the prevalence of particular modes of transport and context [24]. The findings give additional impetus to trauma quality improvement programs, and are timely given the recent establishment of the Australian Trauma Registry and Australian Trauma Quality Improvement Program [25]. It confirms that trauma quality improvement programs can be a cost effective measure to reduce in-hospital mortality following road trauma.

There are a number of limitations to the present study. Firstly, it was conducted at a trauma centre with relatively low trauma patient volumes compared to international standards [9], so specific interventions and improvement programs reported here may not be as relevant or replicated in larger trauma centres. Secondly we focused only on a hospital based intervention and did not seek to estimate the ongoing direct and indirect costs incurred after discharge from hospital or the benefits of survivors in relation to employment and productivity. Furthermore, we did not measure deaths after hospital discharge with increased mortality reported in those sustaining severe trauma several years after the event[26].

Thirdly, mortality trends across the two time periods may simply reflect gradual reductions in major trauma mortality due to clinical improvements over the past two decades. However a recent study at this institution demonstrated that risk adjusted mortality for all major trauma patients only began to decline after 2007 [26]. It is likely that this mortality reduction has resulted from a combination of improved staff training, institution of trauma team activation and massive transfusion protocols as which were all part of the quality improvement process. For instance, the rate of missed injuries (significant injuries not identified during trauma team assessment) between 2003 and 2006, when audits were initiated was 13/782 (1.7% of all major trauma patients) and 4/1244 (0.3% of all major trauma patients) during the post intervention period. It remains unclear which specific quality improvement initiative was primarily responsible for improved patient outcomes. However it is clear that these initiatives require staffing and resources, which would not have been possible without the funding enhancements described above. Fourthly we did not include other important contributors of major trauma such as falls and other non-road trauma related mechanisms. Road trauma was used in this analysis because of defined funding mechanisms in this state that fund road injury costs and rehabilitation, and to allow direct comparisons with costs effectiveness of other road safety initiatives [23,24].

Finally the usefulness of cost effectiveness analyses is context specific and depends on factors such as the ability and willingness of any given society to pay for the intervention. Therefore monetary thresholds for cost effectiveness ratios should be interpreted with caution. The most widely publicised threshold is the $USD 50,000 per QALY gained as a rule of thumb [27]. Expressed in 1997 values, these were arbitrarily based on the costs of renal dialysis at the time. More recently the National Institute for Health and Care Excellence defined a threshold value of £20,000-$30,000 per QALY gained as cost effective [28]. The World Health Organisation standardises cost effectiveness across regions by using three times the Gross Domestic Product per capita as the threshold value [29]. Based on this definition, a threshold of between $60,000 to $90,000 per QALY gained appears to be a reasonable in the Australian context and is consistent with the thresholds described for pharmaceutical interventions in Australia of A$40,000 to A$70,000 per life year gained [30]. Based on these thresholds, the incremental cost-effectiveness ratios of the trauma service improvements would be considered cost-effective even in the worst case scenario using an annual discount factor of 8%.

In conclusion, a program of trauma service enhancements that enabled a quality improvement program between 2007 and 2010 was associated with a significant reduction in severe road trauma mortality at this institution. The funding enhancements were found to be cost effective based on current international and Australian standards and confirm that trauma quality improvement programs can be a cost effective measure to reduce in-hospital mortality from road trauma.

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TABLES AND FIGURES

Characteristics		**Before(2001-2006) N=460**	**After (2007-2012) N=416**	**P value**
Demographics	Age (median IQR) years	38 (24,57)	41 (27,59)	0.09
	Male (%)	328 (71)	324 (78)	0.03
Injury mechanism (%)	Motor vehicle(car)	180 (39)	122 (29)	
	Motorcyclist	56 (12)	87 (21)	
	Pedestrian	161 (35)	128 (31)	
	Cyclist	12 (3)	42 (10)	
	Other	51 (11)	37 (9)	<0.001

Clinical characteristics	SBP<90 (%)	41 (9)	39 (9)	0.81
	ISS (median, IQR)	23 (17,30)	21 (17,29)	0.03
Severe injury (AIS ≥3) by body region (%)	Head	305 (66)	247 (59)	0.03
	Face	75 (16)	87 (21)	0.09
	Neck	4 (1)	2 (0.5)	0.49
	Chest	192 (42)	195 (47)	0.13
	Abdomen	75 (16)	65(16)	0.78
	Spine	47 (10)	43 (10)	0.95
	Upper limb	20 (4)	6(1)	0.01
	Lower limb	122 (27)	116 (28)	0.65
Hospital episode of care characteristics	ICU (%)	326 (71)	223 (54)	<0.001
	Transfer (%)	135 (30)	128 (31)	0.65
	LOS (days)	11(4,22)	9 (4,24)	0.83
	Discharge to rehabilitation	115 (25)	97 (23)	0.56
	Cost weight per patient (median IQR)	4.4 (1.9, 13.3)	4.1 (1.9,12.7)	0.69

Table 1 – Comparison of demographic and injury characteristics in severely injured road trauma patient in the pre-intervention and post intervention groups. IQR = Interquartile range, ISS = Injury Severity Score, AIS = Abbreviated Injury Scale, LOS = length of stay, ICU = Intensive Care Unit admission

	OR	**95%CI**	**P value**

Post intervention period (2007-2012)	0.48	0.27, 0.82	0.01
Age (years)	1.03	1.01, 1,04	<0.001
Sex (male versus female)	0.81	0.46, 1.44	0.48
ISS	1.09	1.07, 1.11	<0.001
Mechanism (versus other)			
Motor vehicle (car)	0.37	0.16, 0.86	0.02
Motorcyclist	0.43	0.15, 1.19	0.10
Pedestrian	0.34	0.15, 0.79	0.01
Cyclist	0.67	0.17, 2.65	0.57
SBP<90	7.27	3.62, 14.60	<0.001
Severe head injury (AIS ≥ 3)	3.33	1.72, 6.46	<0.001
Transfer	0.86	0.46, 1.62	0.65
ICU	0.72	0.40, 1.23	0.28

Table 2 Adjusted odds ratios (OR) for in-hospital mortality ICU = Intensive Care Unit admission, SBP = systolic blood pressure, Transfer = transported by retrieval services from another hospital, ISS = Injury Severity Score. Area under ROC 0.87 (95%CI 0.83, 0.90) Hosmer-Lemeshow test statistic 9.67 8dF p=0.28

Table 3 - Incremental costs, effectiveness and cost-effectiveness of trauma service improvements (expressed in 2012 Australian dollars $AUD)

Discount rate	Intervention cost $AUD	Life years gained (95% CI)	Cost per life year gained (95% CI)
0%	3,629,606	915 (362, 1266)	3967 (2867 - 10027)
3%	3,306,755	499 (197, 690)	6627 (4792 – 16786)
5%	2,847,115	374 (148, 518)	7613 (5496 – 19261)
8%	2,272,410	250 (99, 346)	9090 (6568 – 22954)

CHAPTER THIRTEEN

Health status and return to work in trauma patients at three and six months post discharge – an Australian major trauma centre study

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Keywords

Trauma, health outcome, follow-up

Conflicts of Interest

None Declared

ABSTRACT

Introduction

The aim of this study was to describe post discharge outcomes, and determine predictors of three and six month health status outcomes in a population of trauma patients at an inner city major trauma centre.

Methods

This was a prospective cohort study of adult trauma patients admitted to Royal Prince Alfred Hospital with three and six month post discharge outcomes assessment.

Outcome measures were the Physical Component Scores (PCS) and Mental Component Scores (MCS) of the Short Form 12, EQ-5D, and return to work (in any capacity) if working prior to injury. Repeated measures mixed models and Generalised Estimating Equation models were used to determine predictors of outcomes at three and six months.

Results

One hundred and seventy nine patients were followed up. Predictors of lower PCS scores were lower limb injuries -4.21 (95%CI -7.58, -0.85), and increased injury severity score.. Predictors of decreased MCS were related to mechanism of injury (assault, pedestrian), and previous history of mental health diagnosis. After adjustment, upper limb injuries were the only injuries associated with reduced odds of return to work at 3 and 6 months (OR 0.20, 95%CI 0.07, 0.57).

Discussion

Predictors of poorer physical health status were lower limb injuries and predictors of mental health were related to the mechanism of injury and past mental health. Increasing injury severity score and upper limb injuries were the only predictors of reduced return to work. The results will assist in piloting early post discharge interventions aimed at improving health status and return to work after trauma.

INTRODUCTION

With improved survival after major trauma over the past few decades, the emphasis in trauma outcomes research has shifted from in-hospital mortality to investigating factors that influence long term health outcomes after injury[1-3]. Some of these factors include age[4], severity of injury[5,6], level of education[6], brain injury[7-9], ongoing pain[10] and compensable status[11]. Regardless of the factors involved or specific measures used, there is substantial evidence that seriously injured patients experience ongoing disability months to years after injury[12].

Determining long term outcomes of trauma patients is important to establish and benchmark the effectiveness of systems of care for the injured, and inform policy and research priorities. Some studies have investigated these outcomes on a population or regional level[13, 14]. There are also a number of studies that describe the post injury health outcomes from a single trauma centre perspective[15-17]. Single centre studies have been limited by the use of differing or non-validated Health Related Quality of Life (HRQoL) measures[16], varying follow up strategies and difficulties related to follow up[17].

Given the cost and burden of injury to society and the importance of routinely monitoring post discharge health status, it was felt that an investigation using validated HRQoL measures consistent with population level studies[13] would help establish the feasibility of routine patient follow up at a trauma service level. It would also enable the identification of factors amendable to future post discharge clinical interventions and the value of further outcomes analysis. The aim was therefore to describe post discharge outcomes at a trauma service level, and determine predictors of three and six month health status outcomes in a population of trauma patients at an inner city major trauma centre.

MATERIALS AND METHODS

Setting – The study was conducted at a single inner city Major Trauma Centre in Sydney Australia, with around 600 in-patient trauma team admissions per annum

Design – This was a prospective cohort study with recruitment of eligible patients during in-hospital admission and three and six month post discharge outcomes assessment

Inclusion criteria – Eligible participants were trauma patients who were aged 16 years and over, admitted between July 2012 and July 2013. Trauma patients were defined as those who were transported from the scene by NSW Ambulance Service, underwent a trauma team assessment in the emergency department, subsequently admitted as an in-patient to the hospital and had a tertiary survey performed by the trauma service within 24 to 48 hours of admission.

Exclusion criteria – Patients were excluded if they were transferred from another hospital as the study was designed to inform local follow up procedures, represented with injury following enrolment into the study, persistent vegetative state or expectant death within 72 hours of arrival (to minimise distress to relatives), required high level care prior to injury, unable to consent due to pre-existing cognitive impairments or mental health illness, could not speak adequate English and did not have access to an interpreter at home, or presented after penetrating trauma or self-inflicted injury. These exclusions were based on the need to obtain informed consent prior to enrolment, and expected difficulties associated with poor follow up of patients of non-English speaking backgrounds without access to a translator, and those with penetrating and self-inflected injuries at this institution.

Outcomes – Outcome measures were the Physical Component Scores (PCS) and Mental Component Scores (MCS) of the Short Form 12 (SF-12) Version 2 (acute). Higher PCS and MCS scores denote improved health status. Return to work and EQ-5D items were also assessed.

Enrolment procedure

Eligible patients were identified during routine post admission ward rounds by the trauma team. Study procedures were explained by trained Trauma Clinical Nurse Consultants and written informed consent was obtained from the patient, or assent from their next of kin, prior to discharge from hospital. Follow up telephone calls were conducted by a single Trauma Case Manager. These calls occurred at three months and six months post hospital discharge. Two weeks prior to telephone contact, a reminder letter and study brochure were mailed out to participants addresses, re-explaining the study and the purpose of the interview. If the patient or their next of kin could not be contacted after three attempts over two weeks at both three and six month follow up calls, the patient was considered lost to follow up. Deaths after discharge were checked using District-wide electronic medical records and the NSW Birth Deaths and Marriage Registry.

Data collection

The following data points, based on the Victorian State Trauma Registry[13] were collected;

- Baseline – Age, marital status, residential status, education level attained, pre-injury employment status.
- Three and six month follow up – Three and six month follow up – Short Form 12 (SF-12) Version 2 (acute), EQ-5D, and return to work (in any capacity) if working prior to injury.

Prior to study commencement, a one day field trip to the Victorian State Trauma Registry was undertaken by the trauma service as part of training in follow up procedures and assessment tools. Proprietary scoring software for SF-12 version 2 acute recall (4 weeks) (QualityMetric, Lincoln Rhode Island, USA) and Australian weights and norms[18] were used to calculate PCS and MCS. Data were linked by medical record number and presentation date to this hospital's trauma data registry and electronic medical records to obtain clinical and injury details (mechanism of injury, in-patient length of stay, injury severity score (ISS), intensive care unit admission, transfer to rehabilitation, financial classification (Compensable under NSW Motor Accidents Authority) and comorbidities. Patients were classified as having any medical comorbidity or previous mental health diagnosis based on 10th revision of the International Classification of Diseases Australian modification (ICD-10-AM) coding. Highest education level attained was categorised into university or post graduate level versus secondary or primary school level. A medical student entered baseline and follow data into a separate database which then required linkage (by medical record number and date of presentation) to data in the trauma registry and proprietary SF-12 scoring software.

Statistical analysis

Descriptive statistics were used to present baseline demographics and three and six month outcomes. Means were expressed with standard deviations (SD) and medians with Interquartile Ranges (IQR). Repeated measures mixed models were used to determine predictors of PCS and MCS at three and six months. Covariates used in multivariable models were derived from previous literature[1-13]. To determine the change over time in these outcomes, interaction terms between interview numbers (1= three month and 2=six month follow up interviews) and covariates of interest were included in all models. Generalised Estimating Equations with a log link function were used to compare repeated binary measures such as EQ-5D domains (no problem versus any reported problem), and return to work in the subset of patients who were less than 65 years of age and working prior to admission to hospital. Analyses were conducted using STATA version 13.1 (STATACORP College Station Texas, USA).

RESULTS

Screening and enrolment population

Over a one year recruitment period, 349 patients were assessed for eligibility by the trauma team. Of these 222 eligible patients (64%) were enrolled in the study. When comparing these to the 126 patients who were assessed for eligibility but were subsequently excluded prior to enrolment, there was no difference in mean age 46 (19) years versus 47 (21) years (p=0.77), median (IQR) ISS [8 (IQR 4-17) versus 9 (5-17) p=0.13], proportion of males (78% versus 74%, p=0.40). There was a significant difference in median (IQR) LOS in the patients who were followed up compared to those who were excluded or declined [4 (2-8) days versus 7 (3-15) days, p=0.009).

Comparison of patients studied and those lost to follow up

Of the 222 patients enrolled, nine patients withdrew consent after enrolment and 34 patients were lost to follow up leaving 179 patients available for analysis with an overall follow up rate of 80%. Table 1 describes the baseline characteristics of recruited patients who were lost to follow up or withdrew consent after enrolment (n=43), and the study group (n=179). There were no significant differences between participants and non-participants (lost to follow up or withdrew consent) with respect to age, gender, mechanism of injury ISS, need for intensive care admission or rehabilitation (Table 1).

Outcomes of study population

For the 179 patients studied, the mean (SD) age was 46.2 (20.0) years and 139 (78%) patients were male. The median (IQR) ISS was 9 (4-17) with an ISS>15 in 33% of the study group. The most common mechanisms of injury were falls (32%) and motor vehicle crashes (30%), followed by pedestrians (15%). Three deaths were recorded – one patient prior to discharge, one within three months and one within 6 months of discharge.

Health status outcomes are summarised in Table 2. Mean follow up MCS scores increased between 3 and 6 months but did not reach statistical significance. At 3 months 36% of respondents indicated some problem with usual activities, 37% reported anxiety or depression with 22% reporting psychological problems affecting relationships.

After adjusting for covariates, the presence of any lower limb injury decreased the mean PCS by -4.21 (95%CI -7.58, -0.85). The presence of abdominal injury or head injuries was associated with an increased PCS score between 3 and 6 months, whereas increasing injury severity score was associated with reduced PCS scores between 3 and 6 months (Table 3). Predictors of decreased MCS were related to mechanism of injury (assault, pedestrian), and previous history of mental health diagnosis. After adjustment, overall MCS scores decreased on average between 3 and 6 months, but was not statistically significant (p=0.053).

After adjustment for age, education and compensable status, increasing injury severity scores were associated with reduced odds of return to work (OR 0.98, 95%CI 0.97, 0.99 p=0.004). Upper limb injuries were the only injuries associated with reduced odds of return to work at 3 and 6 months (OR 0.20, 95%CI 0.07, 0.57) after adjustment. Lower limb injuries were associated with a reduced odds of return to work but did not reach statistical significance (OR 0.85 95%CI 0.72, 1.00 p=0.052).

DISCUSSION

The present study was undertaken to describe the three and six month health outcomes of trauma patients discharged after admission to an inner city trauma centre setting. The results demonstrated that whilst unadjusted PCS improved between 3 and 6 months, after correcting for age, mechanism of injury, body regions injured, mechanism of injury and other important covariates, PCS had not improved and MCS scores may have actually decreased. A substantial proportion of patients reported at least some anxiety or depression (37%) and relationship problems related to psychological problems (22%) which did not reduce significantly over the duration of follow up. Between 25% and 30% of patients who were working previously, were still not working at 3 and 6 months. These findings add important insights in the Australian context regarding the ongoing burden of injury after hospitalisation, and will form the basis of future trauma centre based intervention studies

The finding that increasing age, injury severity score and lower limb injuries were associated with reduced physical health status scores contrasts with other studies. Holtslag et al[15] used the sickness impact profile-136 in a cohort of major trauma patients (Injury Severity Score ≥ 16). Age, comorbidities, lower extremity, brain and spinal injuries were predictive of poorer outcomes in that study, whereas injury severity scores were only weakly predictive of outcomes. This may be a reflection of differing injury severities and outcome measured used, but the findings in the present and previous studies in relation to lower limb injuries were consistent with the observation that lower limb orthopaedic injuries were associated with ongoing pain and disability, months after injury[10]. Interestingly, the presence of abdominal trauma and head injury was associated with improved PCS scores between 3 and 6. This may be due to the exclusion of many patients with severe head injury and the low incidence of severe abdominal trauma in general, but underscores the importance of limb injury in determining longer term outcomes.

The lack of improvement in PCS and MCS scores between three and six months after adjustment appears to be consistent with the findings of Gabbe et al[19]. In a longitudinal study of major trauma patients across 24 months, improvements in PCS did not become apparent until 12 months and MCS scores did not improve until around 18 months post injury. The time frame of follow up in the present study differs from others in that the reference point was taken at the date of hospital discharge, not the injury date. The reason for this was that one of the drivers of the present study was to design future specific post discharge clinical interventions at the trauma service level, with any potential post discharge intervention taking place at a certain point after hospital discharge.

The present study differs from previous studies in a number of other aspects. This was a single centre study and was not undertaken at a regional or population level like the Victorian State Trauma Registry[13,19,20]. Patients were identified prospectively at the point of admission to the hospital rather than identified based on post-hoc injury severity scores, length of stay or diagnoses. This contrasts with a similar single centre study from Queensland in a population of patients with medical record coded discharge diagnoses related to injury and hospital length of stay > 24 hours[21]. Given that most of the studies to date have focused on severe trauma (ISS>15), this study adds new information regarding the burden of injury for the majority of admitted patients in Australian Trauma Centres that have mild to moderate injury severity. Mean Physical Component Scores were 39 and Mental Component Scores were 45 at three months follow up in that study, which were lower than scores reported here. Patients in the present study were also recruited and followed up within the trauma service, rather than through external interviewers or self-administered questionnaires mailed out. A study of over two thousand injured patients who were registered with the New Zealand no-fault injury insurance agency[22] found that around 23% of patient reported some degree of anxiety or depression on the EQ5D at three months follow up, which was lower than the proportion (36%) reported in the present study. Return to work in the present study was also higher than those reported in other studies[23,24], and likely reflects differing injury mechanisms, injury severity and the specific focus on hospitalised patients in this study.

Another important finding relates to mental health. Impairments in mental health after trauma are well described in the literature and may be related to pain, financial or interpersonal stress[25]. Harris et al[26] determined that the presence of an unsettled compensation claim was significantly associated with both poorer mental and physical health in a cross sectional study of major trauma patients one and five years post injury. This may be one reason why assault related injuries in particular were associated with lower MCS scores in this study.

Given that mental health domains do not appear to improve significantly, and perhaps deteriorate between 3 and 6 months in this study population, it would appear that any post discharge clinical intervention aimed at improving long term health outcomes will need to address these issues. Such interventions may include telephone counselling and referral to mental health clinicians for more detailed assessment and treatment[27]. Further analysis is underway to determine which baseline and injury factors are associated with poorer physical and mental health after 12 months post discharge, and will inform the design and inclusion criteria for any clinical intervention at this institution.

The study has several limitations, being a relatively small single centre study. Excluding non-English speaking patients who did not have access to a family member who could interpret over the telephone was necessary given to design of this study, but may have introduced bias if such groups were associated with poorer health outcomes in general. Conducting follow up assessments at the level of individual trauma services presents a number of other problems, including standardisation of eligibility criteria, and external validity of findings. Although the process described here was considered feasible at this trauma centre, it would be difficult to ascertain the burden of injury at a regional level or indeed any outcomes of trauma system interventions without a more unified approach[28,29]. Whilst other studies have used the date of injury as the reference point for follow up of severely injured patients, the reference point for this study was the date of discharge from hospital. This was because the study was to form the basis of piloting specific early post hospital discharge clinical interventions, and most of the patients in this study population were mild to moderate trauma with median length of stay of around four days. This was more likely to be representative of the typical patient case-mix at Australian trauma centres.

In conclusion, there was no change in PCS and MCS scores between three and six months post discharge from hospital in this population of trauma patients. The predictors of poorer physical health were increasing injury severity scores and lower limb injuries and predictors of poorer mental health were related to mechanism of injury (assault and pedestrian mechanisms) and past mental health diagnoses. Further studies are required to determine whether specific predictors of poor health status, particularly mental health scores and return to work are amenable to early post discharge clinical intervention.

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COMPLIANCE WITH ETHICAL REQUIREMENTS

The study was approved by the Sydney Local Health District Research Ethics Committee.

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TABLES

Table 1 – Comparison of baseline and injury characteristics of patients who were followed up and those who were lost to follow up or withdrew consent (Non-participants), MAA=Motor Accidents Authority. Rehabilitation = transfer to external or in-patient rehabilitation units

	Participants N=179	**Non participants N=43**	**P value**
Age, years, mean (SD)	46.2 (20.0)	40.6 (15.6)	0.16
Male (%)	139 (77.7)	35 (81.3)	0.59
Married/de-facto (%)	108 (60.3)	33 (76.7)	0.045
Compensable under MAA (%)	86 (48.0)	19 (44.2)	0.65
Pre-existing medical condition (%)	49 (27.4)	16 (37.2)	0.20
Pre-existing mental health diagnosis (%)	26 (14.5)	14 (32.5)	0.004
Injury Severity Score, median (IQR)	9 (4 -17)	9 (5 -14)	0.91

Rehabilitation (%)	24 (13.4)	6 (14.0)	0.93
Mechanism of injury (%)			0.52
Assault	15 (8.4)	7 (16.3)	
Car occupant/driver	17 (9.5)	4 (9.3)	
Motorcyclist	36 (20.1)	9 (20.9)	
Pedestrian	28 (15.6)	3 (7.0)	
Cyclist	16 (8.9)	6 (14.0)	
Fall	61 (34.1)	13 (30.2)	
Other	6 (3.4)	1 (2.3)	
Intensive Care Admission (%)	37 (20.7)	7 (16.3)	0.52
Body region (%)			
Head injury	92 (51.4)	23 (53.5)	0.81
Chest injury	48 (26.8)	8 (18.6)	0.27
Abdominal injury	23 (12.8)	4 (9.3)	0.52
Vertebral injury	34 (19.0)	9 (20.9)	0.77
Upper limb injury	71 (39.7)	18 (41.9)	0.79
Lower limb injury	64 (35.8)	15 (34.9)	0.92
Pelvic injury	12 (6.7)	2 (4.7)	0.62

Table 2 – Health status outcomes at three and six month follow up *Variable converted to binary outcome (no problem versus any problem)

	3 month follow up (n=179)	**6 month follow up (n=178)**	**P value**
SF-12			
Physical Component Score (mean, sd)	45.0 (10.2)	46.8 (10.3)	<0.001
Mental Component Score (mean, sd)	46.9 (11.2)	48.3 (10.2)	0.06
EQ-5D domains			
Mobility (%)			0.30*
No problems	120 (67.0)	126 (70.7)	
Some problems	57 (31.8)	51 (28.7)	
Bed bound	2(1.1)	1(0.6)	
Self-care (%)			0.003*
No problems	153 (85.5)	163 (91.6)	
Some problems	24 (13.4)	14 (7.9)	

Unable to wash/dress self	1 (0.6)	1 (0.6)	
Usual activities (%)			0.007*
No problems	113 (63.1)	131 (73.4)	
Some problems	65 (36.3)	46 (25.8)	
Unable to perform	1 (0.6)	1 (0.6)	
Anxiety or depression (%)			0.88*
None	112 (62.6)	113 (63.5)	
Moderately	49(27.4)	54(30.3)	
Extremely	18(10.1)	11(6.2)	
Pain/discomfort (%)			0.010*
None	68 (38.0)	84 (47.2)	
Moderate	104 (58.1)	86 (48.3)	
Extreme	7 (3.9)	7 (3.9)	
Return to work (if working prior to injury n=125) (%)	92 (73.6)	93 (76.0)	0.31

Table 3 – Multivariable mixed model of SF-12 health outcomes between interview number (1=3 month, 2=6month follow up interview) and covariates, MAA=Motor Accidents Authority, **Highest education level attained

	n = 179 (%)	**Physical Component Score (Mean difference 95%CI)**	**P value**	**Mental Component Score (Mean difference 95%CI)**	**P value**
Age		-0.16 (-0.04, -0.28)	0.007	-0.12 (-0.27, 0.026)	0.10
ISS		-0.41 (-0.13, -0.69)	0.004	-0.10 (-0.46, 0.25	0.57
Gender					
Female	40 (22)	(reference)		(reference)	
Male	139 (78)	0.88 (-2.81, 4.57)	0.64	1.86 (-2.18, 5.90)	0.37
Education**					
Primary/High school/other	76 (42)	(reference)		(reference)	
University/Postgraduate degree	103 (56)	-1.04 (-4.0, 1.90)	0.49	-2.86 (-6.11, 0.39)	0.09
Injury					
Head	92 (51)	4.32 (0.95, 7.68)	0.01	-1.5 (-5.20, 2.19)	0.42
Chest	48 (27)	1.20 (-2.20,4.59)	0.49	1.10 (-2.60, 4.81)	0.56
Abdominal	23 (13)	7.26 (2.61, 11.92)	0.002	2.30 (-2.81, 7.40)	0.38

Vertebral	34 (19)	-0.85 (-4.58, 2.87)	0.65	-0.08 (-4.16, 4.00)	0.97
Upper limb	71 (40)	-1.76 (-4.68, 1.15)	0.24	1.95 (-1.26, 5.15)	0.23
Lower limb	64 (36)	-4.21 (-7.58, -0.85)	0.01	1.90 (-1.78, 5.58)	0.31
Mechanism					
Fall	58 (32)	(reference)		(reference)	
Assault	14 (8)	1.78 (-3.92, 7.47)	0.54	-10.50 (-16.70, -4.27)	0.001
Car	18 (10)	-3.74 (-11.53, 4.05)	0.35	-3.96 (-12.5, 4.58)	0.36
Motorcyclist	36 (20)	-0.41 (-7.39, 6.51)	0.91	-7.10 (-14.67, 0.50)	0.07
Pedestrian	26 (15)	0.92 (-5.97, 7.81)	0.79	-10.62 (-17.82, -2.70)	0.008
Cyclist	17 (10)	5.86 (-0.17, 11.88)	0.06	-1.76 (-8.36, 4.86)	0.60
Other	10 (6)	3.95 (-3.50, 11.39)	0.30	-6.92 (-15.29, 1.46)	0.11
Co-morbidities					
Any medical co-morbidity	36 (20)	-2.7 (-6.38, 0.97)	0.15	1.34 (-2.67, 5.70)	0.51
Mental Health diagnosis	26 (15)	1.63 (-2.31, 5.58)	0.42	-4.63 (-8.96, -0.30)	0.036
Non-compensable under MAA	93 (52)	(reference)		(reference)	
Compensable under MAA	86 (48)	1.85 (-3.98, 7.68)	0.53	-1.67 (-8.06, 4.71)	0.61
Change over time (6 months versus 3 months)		0.04 (-5.09, 5.18)	0.99	-7.27 (-14.62, 0.08)	0.053

CONCLUSIONS AND IMPLICATIONS

CHAPTER FOURTEEN

CONCLUSIONS AND IMPLICATIONS

Lord Kelvin's pronouncement that scientific knowledge could only be advanced through measurement (Chapter 1) formed the basis not just for his scientific works but for the modern organisational management mantra, popularised by the phrase "you can't improve what you can't measure". Though rather simplistic, it holds true for most organisational processes, including those in health care.

It was this fundamental principle that led the trauma service at Royal Prince Alfred Hospital on the path to quality improvement as described in this thesis. The contextual framework for this guiding principle is summarised in Chapter 4. To improve in-patient mortality for severely injured patients, we had to look to and measure quality in, the vast majority of minor trauma patients as well. It required a fundamental shift in the definition of trauma from a purely anatomically based definition of injury severity, to an operational definition based trauma service delivery of care (Chapter 4). This was almost anachronistic - one would normally focus attention on the group of patients where improvements were being sought. It was however, consistent with public health notions of treating upstream "big picture" problems in care, before focusing on downstream effects and complications.

Therefore the over-arching aim of this quality improvement program was to reduce the unacceptably high in-hospital mortality rate (16-20%) in the relatively small group of severely injured patients by focusing quality improvement measures and long term outcome measures on trauma patients in general, regardless of injury severity. Thus, a trauma quality improvement program at this trauma centre, characterised by the use of key performance indicators measured across all domains of acute care, structured data collection on all patients managed by the trauma service and a targeted education program aimed at improving survival after severe injury, has led to a significant reduction in risk adjusted mortality for severe trauma (ISS>15), one of the lowest in Australia according to the 2014 Australian Trauma Registry report[1], as well as the ability to sustainably measure long term post discharge outcomes in trauma survivors.

The implications of these findings are substantial. Based on a comparison of trends in trauma mortality across New South Wales and Royal Prince Alfred Hospital, it was estimated that over 150 major trauma patients were saved as a direct result of the quality improvement program over the past decade. Translated across metropolitan major centres over the past ten years, this program could have resulted in 840 fewer major trauma deaths.

There is still much to do.

Post discharge health status analyses have underscored the importance of providing ongoing care at discharge. At three months after hospital discharge, a substantial proportion of patients were still experiencing functional impairments and over a third experiencing psychological distress. Post discharge outcomes are now being routinely measured and a post discharge trauma clinic has been established at Royal Prince Alfred Hospital. These have all been achieved cost effectively within the trauma service with no further staffing enhancements since 2010. The improvements in major trauma mortality have been maintained with current in-patient mortality (ISS>15) of around 7.4% in 2016. Perhaps most striking is the overall perspective from 2006 to 2016. Figure one presents the trend in major trauma (Injury Severity score >15) at Royal Prince Alfred are compared to overall New South Wales major trauma mortality based on current available data[2] and the data presented in this thesis. The trends demonstrate a clear divergence from 2006 onwards. The figure probably underestimates the actual difference in mortality trends as the available data from New South Wales is inclusive of data from Royal Prince Alfred Hospital.

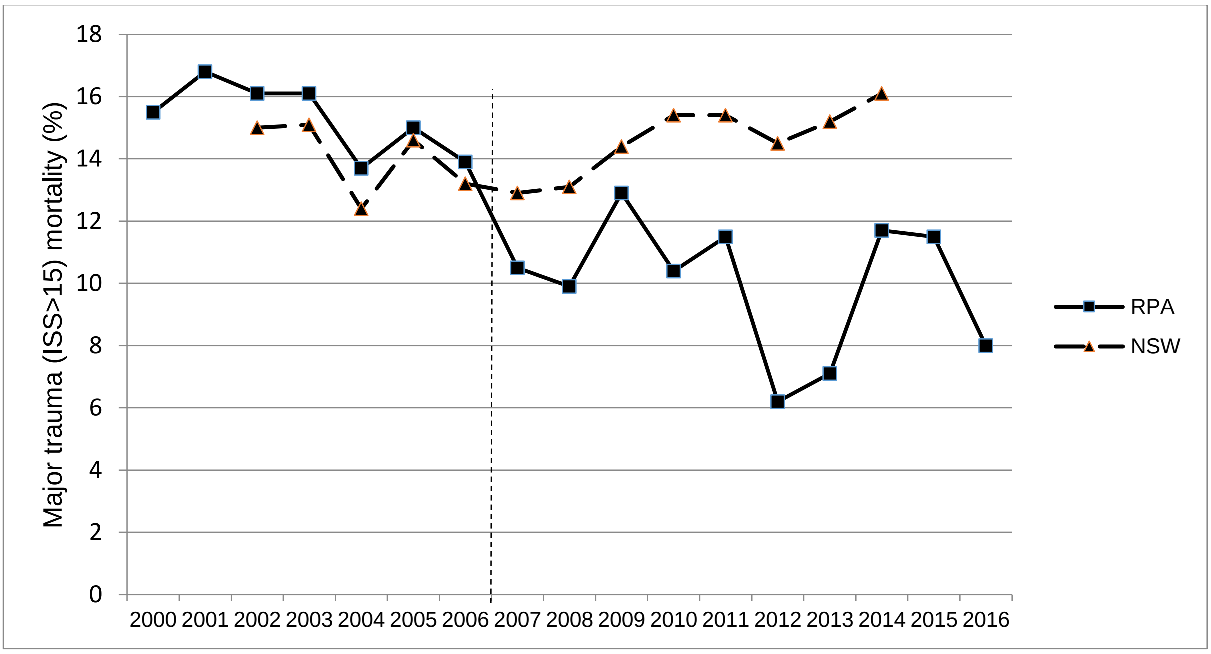

Figure (above) – In-patient mortality from major trauma (Injury Severity Score (ISS) >15) at Royal Prince Alfred Hospital and overall New South Wales (NSW). Dotted line denotes commencement of trauma quality improvement program at RPA. Data from 2016 is up to August only.

Although trauma systems as a whole have been shown to improve survival and outcomes after major trauma, little has been done to evaluate the specific components that may contribute to these observed improvements. Trauma quality improvement programs are a vital way of monitoring and improving the quality of patient care in most trauma centres[3,4]. This body of work was the first and only one to systematically evaluate the impact and cost effectiveness of one such program over a long period of time, and benchmark these trends against overall system wide trends across the whole trauma system in New South Wales. In a multi-centre comparison of centres in Quebec, Liberman et al[5] found that the presence of pre-hospital notification (OR 0.61 95%CI 0.39, 0.94) and the presence of a quality improvement program (OR 0.44 95%CI 0.20, 0.94) were the strongest predictors of reduced mortality at trauma centres. Increasing trauma centre volume was also found to be a predictor of improved survival but the effect was low (OR 0.98 95%CI 0.97, 0.99). The transferability of the approach described in this thesis is suggested by a study by Kesinger et al[6] that showed that the use of standardised protocols during trauma resuscitation was associated with a decrease in hospital length of stay in a pre and post intervention study conducted at a trauma centre over two years in Columbia (13.4 versus 11.8 days p=0.017) and survival improved although this did not reach statistical significance (3.9 versus 2.9% p=0.08). Perhaps the study that most closely aligns with the conceptual framework of this thesis was one performed by Sarkar et al in Michigan US[7]. In this study, trauma activation criteria were revised with the introduction of standardised resuscitation and massive transfusion protocols, similar to the ones described in this thesis. Over a four year period investigators noted an observed to expect ratio for mortality associated with the intervention period of 0.64 (95%CI 0.42, 0.86). These studies provide further evidence that the approach used in this study may be transferable to other institutions.

LIMITATIONS

There are other acknowledged limitations and these have been discussed extensively throughout the works presented in this thesis. The evaluation was conducted at a single centre which may limit the applicability of our findings in other settings. Most trauma quality improvement programs, by virtue of the fact that most hospitals vary in institutional based practices and processes, will vary. However the clinical indicators and data management principles used in this project are not unique and can be transferable to other settings[8]. The cost effectiveness analysis used financial enhancements to this hospital between 2007 and 2009, comprising mainly staffing increases. It did not account for the costs and benefits of increasing trauma expertise over time, particularly in the field of Intensive Care Medicine or other unmeasured improvements to the NSW trauma system. Improved road trauma mortality across NSW during the time period may have also confounded the results. We were unable to assess for an improvement in long term outcomes associated with the quality improvement program, as these outcomes were not collected prior to the intervention. An improvement in functional outcome was suggested however in Chapter 11 with a reduction in rates of discharge to in-patient rehabilitation after severe injury.

The use of in-hospital mortality for severe injury (ISS>15) as the main outcome is acknowledged as a limitation of this thesis. Nearly all trauma quality improvement programs evaluated and reported in the scientific literature (see Chapter 2) have used some measure of in-hospital mortality as a starting point to assess clinical effectiveness. It is an accepted albeit crude measure of major trauma centre function but one that can be benchmarked across centres and different trauma systems. As discussed in Chapter 4, severely injured patients make up less than 20% of all trauma service patients, and assessing outcomes using valid measures for the remaining 80% patients remains an important priority. This was addressed partly in Chapter 13 which outlines a program of work to assess long term health status in survivors of trauma. It needs to be stressed however, that the core function of designated major trauma centres in an inclusive trauma system (Chapter 2 and 5) is the resuscitation, definitive care and recovery from severe injury. The complexities of defining severe injury within the context of a trauma system have been discussed in Chapter 4, however it remains that severely injured patients (ISS>15) have the highest mortality and are associated with the poorest long term outcomes (Chapter 13). The priority for major trauma services in the first instance is to increase survival for such patients through organised and effective pre-hospital and hospital acute care, before any other consideration.

To place this into perspective, at this institution, the mortality for minor trauma patients (ISS<12) has been around 0.25%, and has remained unchanged over the past decade. Evaluating mortality changes in this cohort would not have been a valid outcome measure, as in-hospital deaths in this group were rare and any changes unlikely to reflect gaps in acute care. Therefore, although the trauma quality improvement program was directed at the trauma service as a whole, and identifying gaps in care across all trauma patients, the ultimate objectives of the program were to reduce mortality in severely injured patients, and evaluate the health status of trauma survivors. Other measures used in the evaluation of the trauma quality improvement program included length of stays, rates of discharge to rehabilitation and post discharge health status.

The thesis could have explored rates of in-hospital complications, such as nosocomial infections, missed injuries and unplanned readmissions. These are currently monitored at a state-wide level but were not the specific objectives of this thesis. The program of work outlined in this thesis were directed at improving survivability after severe injury, but inclusion of these and other measures of in-hospital complications would have strengthened the findings of this thesis with respect to quality of care within specific domains. It was therefore not determined what aspect of the quality improvement program led to the most benefit in terms of mortality benefit. It is difficult to study individual components of this program such as education or audits or policy implementation as these elements are all inter-dependent. Although separate evaluations of specific clinical indicators was beyond the scope of this study, important clinical indicators involving triage and radiology usage at RPA have already been audited and published in separate studies[9,10]. For instance, triage protocols have been benchmarked according to current American College of Surgeons standards for undertriage and overtriage. Time to definitive care within two hours of injury for those with severe head injury has also been audited and published. A review of Code Crimson activations is also currently underway at this institution.

Another limitation that was not addressed in Chapter 11 was the change in AIS injury severity coding from the 1998 to 2005 version that was introduced at RPA around 2010. The changes in coding were largely limited to the coding of intracranial haemorrhages with very small bleeds downgraded in injury severity. The net effect was a reduction in the severity of head injuries with clinically insignificant pathologies. Although these changes may have resulted in misclassification error, using the same AIS coding version throughout the time series would have biased the hypothesis away from the null, strengthening the results of the study.

The strengths of this thesis is that the time series analysis at least in theory would have accounted for long term underlying trends, and presented overall trends in New South Wales as a comparator. There are many other aspects of quality that were not measured in this thesis. Indeed, mortality and long term health status are only two of many components of clinical effectiveness. Other outcomes that could have been measured include length of stay, rate of complications such as missed injuries and unexpected readmissions to the Intensive Care Unit, and patient satisfaction.

IMPLICATIONS FOR ROYAL PRINCE ALFRED HOSPITAL

Although RPA has a long history of trauma care, it is still relatively small in terms of major trauma volume and in the context of the current NSW Trauma system. No previous study has evaluated a trauma quality improvement program with respect to mortality benefits in his context. The evaluation project was undertaken over six years. The major trauma mortality rate for 2015 was 11% and the year to date figure for 2016 was 7.4%, suggesting that the improvements were sustained. This is illustrated in the figure above and attached in the 2016 RPA Trauma Annual Report as part of the Appendix. It would be interesting to investigate whether the same outcomes could be achieved with increasing volumes of trauma patients and increasing referrals from rural locations which may be part of further iterations to the State Trauma Plan.

Given the initiation of post discharge health outcome assessments, the Trauma service has been able to commence a project evaluating post discharge care of trauma patients in a weekly multidisciplinary clinic. The findings of the health status analysis indicate a substantial proportion of patients (37%) experiencing some form of psychological distress which did not improve with time between 3 and 6 months. Much of this may be related to uncertainty around recovery and financial concerns. However this has led directly to referral pathways for trauma patients to access post discharge mental health support and post traumatic amnesia testing. It has also led to a trial of the post discharge trauma clinic designed to optimise patient education and post discharge care in an effort to improve health status at follow up. The outcomes of this randomised control trial are due in late 2017. Unfortunately, post discharge outcomes were not measured prior to the implementation of the quality improvement program, so that changes in long term outcomes as a result of improved quality of care could not be described as part of this thesis. However the results reported in this thesis provide a useful baseline against which any further trauma service enhancements may be evaluated.

There are ongoing challenges to the functioning of the trauma service, factors likely to adversely influence the quality of care going forward. These include endemic hospital overcrowding, which can affect the availability of appropriate intensive care and ward beds for injured patients as well as Operating Theatre availability. The rapidly ageing trauma population (Chapter 8) is likely to place further strains with increasing costs and complexity of care, longer lengths of stay, increased need for subacute and rehabilitation beds and improved care coordination by trauma and geriatric case managers. Staffing requirements for seven day a week and after-hours senior trauma clinician coverage, including case managers continues to be an issue at this hospital and others. All these factors can influence the clinical effectiveness of quality improvement programs. Technological advances such as the advent of Interventional Radiology (Chapter 7) in major trauma will necessitate not just changes in models of care but re-evaluation of several key performance indicators relating to operative management and definitive care. Both the ageing population and technological advances will fundamentally change how trauma care is delivered over the next few decades. With respect to the discussions in this thesis, trauma in the very elderly may force trauma services to re-evaluate the very definition of trauma, the utility of heroic life-saving procedures outlined in Chapter 7 and goals and costs of these clinical interventions.

IMPLICATIONS FOR THE NSW TRAUMA SYSTEM

This thesis has added important scientific knowledge to the field of quality improvement in health care. The publications contained herein were the first in Australia to systematically evaluate and report on the clinical and cost effectiveness of a trauma quality improvement program over a decade. To the authors' knowledge, it was the first in the world to evaluate such a program using time series analyses. The trauma quality improvement program consisted of three main components: 1) Identification of key performance indicators, representing benchmarks for good clinical care, 2) Systematic data collection of these indicators on all trauma patients, 3) Structured education and training of trauma clinicians at the hospital based around these benchmarks for good clinical care. A structured approach such as this can be replicated across many trauma centres and it requires no investment in new treatments or technologies.

Although only a single centre study, the findings have a number of potential implications for other trauma centres, particularly in New South Wales. Firstly it demonstrated the importance measuring outcomes and clinical indicators across the whole trauma service and on all trauma service patients, not just those who are severely injured. Currently the minimum dataset submission requirements for State-wide data only include patients with an Injury Severity Score >12 or who have died from injury. No evaluation of trauma triage, a fundamental part of any trauma system or trauma activity within hospitals, is possible without expanding the inclusion criterion for mandatory data collection to include all trauma patients (Chapter 4). Secondly it underscored the importance of linking routine trauma data collection with routine quality assurance activities. This is currently facilitated in NSW by the inclusion of standard American College of Surgeon-based audit filters into the State-wide trauma registry, but is not currently part of the minimum dataset for major trauma patients. Such valuable data currently cannot be aggregated and reported on at a State-wide level. Without this capability, it is difficult for governance agencies responsible for trauma system coordination to measure and improve trauma care across a regionalised trauma system. Quality assurance filters therefore need to be included as part of mandatory reporting requirements.

Thirdly, this thesis sought to re-define a trauma patient in a way that enabled this department to effectively monitor and improve quality of care. Previous definitions of trauma only defined it with respect to arbitrary injury severity scores and hospital resource utilisation. This is useful from a descriptive and data modelling perspective, but has limited value to clinicians and patients. Thereafter a trauma patient was defined as a patient that has been “referred” to the trauma service (either by Ambulance or by activation of local trauma triage protocols) and essentially managed by the trauma system. This would be analogous to a cardiology patient being viewed as one referred to and managed by a Cardiology service - not defined simply by the severity of their final cardiac diagnosis. Although there are limitations in the use of this definition, this thesis has shown that it can be useful from a clinical and quality management perspective.

Another definition of major trauma was suggested in one of the initial papers exploring the burden of injury and age specific trends in injury presentations. This was a composite of urgent triage category in the Emergency Department (all trauma team activations are classed as triage category 1 or 2), and transfer of patient directly to the Operating Theatre or Intensive Care Unit or death in the Emergency Department. The appeal of this definition is that it is an entirely a functional one, which can be linked to existing administrative Emergency Department databases such as the New South Wales Emergency Department Data Collection Registry. Further studies are required to investigate how this definition correlates with existing definitions of major trauma. Given this, the possibility exists for estimates of the burden of critical trauma to be routinely measured using existing administrative databases. Using this definition, it was estimated that up over half of all critically injured patients actually present to non-major trauma centres in NSW, adding weight to the argument that current inclusion criteria for trauma registry data collection grossly underestimates the burden of major trauma in a state like NSW. The same study also highlighted the challenge in managing the growing proportion of elderly major trauma patients. Although the principles of trauma management are essentially unchanged, the management of elderly trauma patients adds varying levels of complexity in relation to co-morbidities, appropriateness of invasive therapies, and expectations and goals of therapy, particularly in the Intensive Care Unit setting.

To address this emerging challenge, the New South Wales Trauma System will need to implement models and networks of care to address the specific needs of older Australians. These include an emphasis on allied health, aged care assessment and subacute rehabilitation bed capacity. Over 30% of all major trauma admissions are over the age of 65 years. As discussed in the paper on age related injury trends, it may not be long before trauma services incorporate formal geriatric clinicians as part of the trauma team to coordinate care and identify appropriate priorities for recovery earlier in the patient journey.

Finally, the monitoring of post discharge health status outcomes is currently being considered by the New South Wales Institute of Trauma and Injury Research. These patient centred outcomes are important in evaluating the ongoing care of injured patients to ensure that the trauma system is meeting their needs even after a trauma patient is discharged from hospital. The study investigating three and six month post discharge outcomes provided important insights into the feasibility of this approach which was based on outcomes collected by the Victorian State Trauma Registry. The study has proven to be very useful in providing insights into patient's needs as they recover in the community and has instigated the trauma clinic intervention study described above.

CONCLUSION

A trauma quality improvement program at Royal Prince Alfred Hospital between 2007 and 2010 was associated with significant, sustained and cost-effective reductions in major trauma mortality compared to overall mortality trends in New South Wales. This statement is based on the results of a formal time series analysis (Chapter 11), and cost effectiveness analysis (Chapter 12). The program has also enabled the initiation of post discharge outcomes measurement in an effort to optimise patient health after discharge from hospital that will further inform ongoing patient needs and refinements to current trauma models of care (Chapter 13).

Now that the value of a trauma quality improvement program has been firmly established, at least in this hospital, it provides a basis for further measurement and improvements. These include the measurement of long term health outcomes, the influence of quality of care on these outcomes and the evaluation of other quality control tools such as advanced decision support systems and simulation. Although Lord Kelvin was held in the highest esteem as a scientist, particularly for his work in thermodynamics, he was sceptical of technological advances, believing man-made flight could never become a practical reality. It would be convenient to think that Lord Kelvin was wrong. In truth, it was that in time, others simply found a better way to view the world and its possibilities. That is the beauty of the scientific process. And the same is true for the work presented in this thesis. It would be convenient to think that the program of research presented in this thesis was the be all and end all of trauma quality improvement. It is not. But ultimately it is hoped that this body of work will inspire others to reach for newer and better ways of saving lives and improving the outcomes of injured patients we care for.

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APPENDIX

SLHD: Royal Prince Alfred Hospital Procedure

Trauma Service: Trauma Team Activation Procedure	
TRIM Document No	
Policy Reference	RPAH_PC2016_021
Related MOH Policy	N/A
Keywords	trauma
Applies to	Bone Joint and Connective Tissue Critical Care Neurosurgery Clinical Streams, Division of Surgery
Clinical Stream(s)	Respiratory & Critical Care Services Laboratory Services Medical Imaging Services Neurosciences, Bone and Joint, Plastics and Trauma Surgical Services
Date approved GM, RPA	*08/07/2016*
Date approved by RPA Policy Committee	*21/06/2016*
Author	Director, Trauma Service
Status	Active
Review Date	*July 2021*
Risk Rating	M
Replaces	RPAH_PD2015_052

Version History V1	
Date	11th July, 2016

Trauma Service: Trauma Team Activation Procedure

Contents

SLHD - RPA Trauma Team Activation Procedure

1. Introduction

The RPA Trauma Activation procedure uses a validated tool to triage trauma patients arriving at RPA.

2. The Aims / Expected Outcome of this Procedure

To ensure that injured patients who would benefit from a coordinated team response are accurately triaged.

3. Risk Statement

SLHD Enterprise Risk Management System (ERMS) Risk # 783 - Provision of Care:

- Trauma response and mobilisation of resources to adequately manage traumas in Emergency Department.

4. Key Principles

The purpose of trauma activation criteria is to accurately triage those injured patients who benefit from a coordinated team response. Such patients include those with;

1. Potentially life threatening injuries
2. Multiple or complex injuries
3. Injuries requiring urgent or immediate surgery

In addition, there should be a lower threshold for initiating trauma team response in the following injured patients;

1. Elderly, paediatric or pregnant patients
2. Patients with a history of anticoagulant use
3. Any doubt about the mechanism of injury
4. Multiple injured patients or situations where the management of injured patients could be compromised as a result Emergency Department activity or access block

There are 3 tiers of Trauma Team activation at RPAH

1. Full trauma team activation
2. Trauma consult
3. Paediatric trauma activation

5. Scope

Emergency Department, Operating Theatre Nurse Unit Managers, Intensive Care Unit, Anaesthetics, Radiology and Division of Surgery.

5.1 Trauma Team Members

Staff notified as part of the Trauma team activation include:

- Emergency Department Nurse Unit Manager 1
- Operating Theatres Nurse Manager
- Emergency Department Staff Specialist / Registrar
- Surgical Registrar
- Anaesthetics Registrar
- Intensive Care Unit Registrar
- Trauma CNC (in hours)
- Radiographer

- Social Worker (in hours)
- Emergency Department CNC and CNE

5.2 Activating the Trauma Team

The RPAH Trauma Team is activated by dialling 222 for;

- Pre-hospital notification of direct or transferred trauma patient via "bat phone"
- Patients identified by Triage Nurse as satisfying full trauma team activation criteria
- Doctor or Registered Nurse review of patient in ED who subsequently meets Full Trauma or Trauma Consult criteria.

6. Procedure

MANDATORY CRITERIA FOR FULL TRAUMA TEAM ACTIVATION

Any one of the following criteria in a trauma patient mandates full trauma team activation (dial 222).

VITAL SIGNS

Systolic Blood Pressure <90mmHg

Respiratory rate <10 or >29

Heart rate <50 or >120bpm

Glasgow Coma Score 13 or less or fitting

Age over 65 with Systolic Blood Pressure <100mmHg or Glasgow Coma Score 14 or less

MAJOR INJURIES

Any evidence of airway obstruction or compromise

Penetrating injury

Flail chest

Suspected spinal cord injury

2 or more long bone fractures

Multiple body region injuries

Traumatic amputation or crush injury to limb proximal to wrist or ankle

Burn greater than 20% BSA associated with trauma

At the discretion of or upon review by any Doctor or Registered Nurse

Trauma transfer from another hospital

6.1 Criteria for direct notification of trauma surgeon and emergency consultant

DIRECT NOTIFICATION OF TRAUMA SURGEON AND EMERGENCY CONSULTANT BY TRAUMA TEAM

- Systolic blood pressure< 90mmHg confirmed in resuscitation bay
- Administration of blood products in resuscitation bay
- Arrival of 3 or more simultaneous trauma patients
- Consensus relating to treatment or definitive care not able to be met
- Any gunshot wound to the torso/neck

6.2 Criteria for activation of trauma consult

CRITERIA FOR ACTIVATING TRAUMA CONSULTS

If a patient meets the following mechanism criteria without major injury or vital sign abnormalities, the Triage Nurse **may** activate a Trauma Consult (dial 222 and request "Trauma Consult"). This response involves the ED and Surgical Registrar. If a Trauma Consult is considered by the Triage Nurse to be unnecessary in a patient meeting these criteria, the Triage Nurse must contact and discuss the case with the ED Staff Specialist or Acute Registrar on 50000:

- Any motor vehicle accident (MVA) at high speed (>60km/hr)
- Ejection or rollover or death of vehicle occupant
- Pedestrian struck by moving vehicle
- Bicycle accident >20km/hr impact
- Fall >3m
- Motorcycle accident resulting in separation from vehicle
- Prolonged extrication time > 20 minutes
- Injury associated with history of anticoagulants or antiplatelet agents

Trauma Consults are particularly useful in patients with multiple minor injuries who require admission under the Trauma Service. However Trauma Consults are designed for the urgent review of patients with acute injuries, and should NOT be activated for patients in ambulatory or non-monitored areas of ED. If a trauma patient has been triaged to ED Fast Track or other non-monitored area, the patient must be reviewed by a senior ED doctor prior to any decision to activate a Trauma Consult. A Trauma Consult may be subsequently upgraded to Full Trauma Team activation if the patient's condition changes or the injuries are deemed to be serious enough.

SPECIAL CONSIDERATIONS

The following circumstances require additional expertise to be notified and present as soon as possible after notification:

- Penetrating chest injuries – Cardiothoracic Registrar or Consultant
- Trauma in Pregnancy (>20 weeks gestation) – Obstetric Registrar or Consultant
- Paediatric Trauma (< 15 years of age) – Paediatric Surgeon on Call
- Head injury with GCS <9 or lateralizing signs – Neurosurgical Registrar or Consultant
- Pelvic fracture with haemodynamic instability – Orthopaedics Registrar

If the General Surgical Registrar or Anaesthetics Registrar are unable to attend, they must make direct contact with the Resuscitation room or trauma team leader on 54705

6.4 Paediatric Trauma Activation

Paediatric full trauma activation:

Any one of the following criteria associated with a traumatic mechanism mandates full paediatric trauma activation.

Dial 222 & say Full Paediatric Trauma to Resus.

Any abnormal Vital signs:

	Hr max	RR max	SBP min
Neonate	170	50	70
Infant (1 yr)	160	45	80
Toddler (2 yr)	150	40	80
Child (5 yr)	130	35	90
Tween (12 yr)	120	30	90
Adult >12yr	120	29	90

OR

- Any Resp Rate <10
- Spo2 <90%
- GCS <14 or fitting post Trauma
- Cold/pale /clammy = Bleeding until proven otherwise

OR

Any major injuries: As per adult activation criteria

Plus:

- Burns to face
- Full/Partial thickness burn greater than 5% BSA associated with trauma in child
- Upon review by doctor or registered nurse

Paediatric trauma consults

Mechanism of injury:

(If mechanism only and normal vitals = Paediatric Trauma Consult)

Mechanism of injury as per adult activation criteria

Plus:

- Fall >3m (or twice the standing height of child)
- Upon review by doctor or registered nurse

Dial 222 & say Paediatric Trauma Consult to Resus

Trauma consults activation criteria can only be downgraded by the Emergency consultant or senior registrar in charge of the department after review of the child

6.5 Paediatric Anaesthetics after hours

1. Patients < 2 years old will not be anaesthetised for emergency surgery (in or out of hours).
2. Patients 2-6 year olds will not be anaesthetised at night (6pm-8am) unless the injury is life or limb threatening.
3. When delayed (above), children will be given high priority on the emergency list the next morning.
4. Children > 6 yrs are managed by the adult anaesthetic team.

Exceptions to this procedure require agreement between the consultant surgeon and the on-call consultant paediatric anaesthetist.

This procedure does not preclude any consultant anaesthetist treating a paediatric patient where there is immediate threat to life or limb.

NOTE: Staff paged on paediatric full Trauma = Trauma surg reg, Anaesthetic reg, ICU Reg, Paediatric consultant (in hours Mon-Friday), Trauma CNC & Case manager.

Staff paged on paediatric Trauma Consult = Trauma surg reg, Paediatric consultant (in hours Mon-Friday), Trauma CNC & Case manager

7. Key Performance Indicators and Service Measures

Case by case auditing and monthly review by Trauma Directors at RPAH Trauma Committee Meeting

8. Definitions

BSA	Body surface area
ED	Emergency Department
GCS	Glasgow Coma Score

9. References

- **Policy Author:** Michael Dinh, Trauma Co-Director; Chris Byrne, Trauma Co-Director; Liz Leonard, Trauma CNC, Karen Creighton, Trauma CNC.
- **Policy Authorisation:** RPAH Trauma Committee
- NSW Institute of Trauma and Injury Management http://www.itim.nsw.gov.au/

Policy Directive

NSW GOVERNMENT | Health Sydney Local Health District

Massive Transfusion Protocol (MTP)

Document No: SLHD_PD2014_012

Functional Sub-Group: Clinical Governance

Summary: The Massive Transfusion Protocol (MTP) applies to patients with:

- Actual or anticipated transfusion of 4 units of Red Blood Cells (RBC) in less than 4 hrs, + haemodynamically unstable, +/- anticipated ongoing bleeding
- Severe thoracic, abdominal, pelvic or multiple long bone trauma
- Major obstetric, gastrointestinal or surgical bleeding

Approved by: Director, Clinical Governance and Risk

Consultation: SLHD Patient Blood Management & Transfusion Committee
General Managers

Publication (Issue) Date: May 2014

Next Review Date: May 2019

Replaces Existing Policy: SLHD_PD2013_042 - SLHD Massive Transfusion Protocol (MTP)

Previous Review Dates: September 2013
March 2010

Document No: SD14/2943

Note: Sydney Local Health District* (SLHD) was established on 1 July 2011 following amendments to the Health Services Act 1997 which included renaming the former Sydney Local Health Network (SLHN). The former SLHN was established 1 January 2011, with the dissolution of the former Sydney South West Area Health Service (SSWAHS).

SLHD Massive Transfusion Protocol (MTP)

CONTENTS

Author: SLHD Haemovigilance CNC

Endorsed by: SLHD Patient Blood Management & Transfusion Committee

SLHD Massive Transfusion Protocol (MTP)

1. Introduction

There are no universally accepted definitions of critical bleeding or massive transfusion. For the purpose of this protocol, the definitions suggested within the Patient Blood Management Guidelines have been adopted:

Critical bleeding – Major haemorrhage that is life threatening and likely to result in the need for massive transfusion

Massive transfusion – In adults, a transfusion of half of one blood volume in 4 hours, or more than one blood volume in 24 hours (adult blood volume is approximately 70mL/kg).

(i) The Risks Addressed by this Policy

- Clinical risk to patients related to the management of critical bleeding and massive transfusion
- Corporate risk associated with increased length of hospital stay and exposure to complaints or legal action and blood product wastage

(ii) The Aims / Expected Outcome of this Policy

All patients requiring massive transfusion will be managed in accordance with current evidence based practice and National Patient Blood Management Guidelines
http://www.clinicalguidelines.gov.au/search.php?pageType=2&fldglrID=1844&

Wastage of blood products associated with Massive Transfusion will be minimised.

2. Policy Statement

Coagulopathy develops rapidly during massive transfusion. Major trauma and hypothermia are also risk factors for coagulopathy. In major trauma, coagulopathy begins prior to arrival in hospital. The purpose of this protocol is to:

- Ensure clotting factors are transfused early during massive transfusion to avoid dilutional coagulopathy
- Ensure the treating team receives blood products rapidly without being required to order individual products.

3. Principles / Guidelines

(i) Criteria for activation of MTP

The MTP should be activated for patients with any of the following:

- Actual or anticipated transfusion of 4 units of Red Blood Cells (RBC) in less than 4 hrs, + haemodynamically unstable, +/- anticipated ongoing bleeding
- Severe thoracic, abdominal, pelvic or multiple long bone trauma
- Major obstetric, gastrointestinal or surgical bleeding

(ii) Method of activation

The Massive Transfusion Protocol may be activated by:

- A senior clinician can contact Blood Bank to activate
- A 5th unit of Red Blood Cells is ordered within a 4 hour period. In this case, Blood Bank will contact the medical team to determine whether the protocol should be activated for ongoing bleeding
- Trauma Code Crimson Royal Prince Alfred Hospital – Trauma Service Trauma Code Crimson Protocol RPAH_PD2013_019 (RPAH only) results in automatic activation

http://intranet.sswahs.nsw.gov.au/SSWPolicies/pdf/RPA/RPAH_PD2013_019.pdf

The MTP will generally NOT be activated for Liver Transplants and Cardiac surgery

(iii) Patient management

Note: Please see also Appendix 1: MTP Flowchart

Haemorrhage control: early consultant input to control bleeding

  - Identify cause
  - Initial measures: compression, tourniquet, packing
  - Surgical assessment: early surgery or angiography to stop bleeding

- Tolerate permissive hypotension (BP 80–100 mmHg systolic) until active bleeding controlled. A higher target BP is appropriate in head injury and pregnancy. See also special clinical situations.
- Avoid excessive crystalloid
- Prevent or correct hypothermia: Active patient warming and fluid warming are essential. Monitor core temperature - either rectal or nasopharyngeal.
- Prevent or correct hypocalcaemia: check Ca^{++} regularly and replace as required.

- Haematological Tests immediately then every 30 – 60 mins: FBC, Coag Screen, Fibrinogen, Biochemistry. Send specimens at regular intervals but do not delay transfusion of blood products while waiting for results. Inform laboratory that urgent coagulation testing is required with results rung through to the point of care.
- Arterial blood gas analysis including Ca^{++} immediately then every 30 – 60 mins.
- Consider cell-saver if personnel and equipment available.

(a) Specific surgical considerations

If significant physiological derangement, consider damage control surgery or angiography

(b) Resuscitative Aims for Massive Haemorrhage:

Note: Do not use haemoglobin alone as a transfusion trigger. Haemoglobin results should be interpreted in the context of haemodynamic status, organ perfusion and tissue oxygenation.

Aim for:

1. INR < 1.5; PT less than 16 seconds; a PTT less than 42 seconds.
2. Fibrinogen greater than 1.0 g/L
3. Platelets greater than 50 × 10^9/L
4. pH 7.35 - 7.45
5. Core Temperature greater than 35.5 degrees centigrade
6. Base Excess greater than -3.0

Poor prognostic values: SBP < 70 mmHg, Temp < 34° C, Base Excess < -6, pH < 7.1.

(c) Special Clinical Situations

Special Clinical Situations	
Warfarin	Add Vitamin K, prothrombinex/FFP
Obstetric haemorrhage	Early DIC is often present; consider cryoprecipitate
Head injury	Aim for a platelet count of greater than 100 × 10^9/L Permissive hypotension contraindicated

(iv) Blood Product Shipment Details:

Blood bank will thaw frozen products in advance and issue shipments upon request according to the following schedule:

- **First shipment: 4 units of Red Blood Cells and 2 units FFP**
- **Each shipment thereafter**: 4 units Red Cells and 4 units FFP and

- **Second shipment and alternate shipments thereafter:** 1 Pooled Platelets (Note: 1 pooled platelets = 4 of the old units)
- **Third shipment and alternate shipments thereafter**: 10 units Cryoprecipitate (Note: 10 units cryoprecipitate = 3-4g dose fibrinogen)

Important: Although the first shipment will routinely contain only 2 units of FFP, clinicians are able to contact blood bank to request that the additional two units are thawed at the time of protocol activation.

Note: If uncrossmatched group O Rh (D) Negative RBCs are transfused prior to crossmatching, Blood Bank will also supply non group-specific fresh frozen plasma (Group-A).

Additional products may be ordered based on results of testing or clinical impression.

Suggested targets are:

- Further platelets if platelet count ≤ 50 x 10^9/L (≤100 x 10^9/L in head injury)
- Further FFP if INR > 1.5
- Further cryoprecipitate if fibrinogen ≤ 1.0 g/L

(a) Blood Product Dosage:

- Platelet count < 50x10^9/L: give 1 pooled platelets
- INR > 1.5: give FFP 15ml/kg
- Fibrinogen < 1.0g/L: give cryoprecipitate 8-10 units

(v) Adjunct Medications

(a) Tranexamic Acid

Indications

- Trauma patients requiring blood transfusion provided dose can be administered within 3 hours of the injury.
- Any other massive transfusion at discretion of treating team.

Dosage

- 1 g infused over 10 minutes followed by 1 g over 8 hours.

(b) FACTOR VIIa

- Not routinely indicated. See Factor VIIa policy (Attachment 6, SLHD_PD2013_049 – page 43) http://intranet.sswahs.nsw.gov.au/SSWPolicies/pdf/SLHD/SLHD_PD2013_049.pdf
- Consider use in consultation with haematologist after attempting to correct fibrinogen, pH, temperature and platelet count

(vi) Protocol Discontinuation

Blood bank must be instructed to discontinue the MTP as soon as massive transfusion is no longer required so that product wastage associated with massive transfusion is minimised. During a massive transfusion, blood bank thaws frozen products in advance. Unused products can be released for other patients once this protocol is discontinued. Notify Blood Bank when either:

- Bleeding is controlled and massive transfusion is no longer required, or
- Further resuscitation is deemed futile and transfusion ceased.

4. Performance Measures

Number of adverse outcomes or incidents notified on the Incident Information Management System (IIMS)
Product wastage associated with MTP activation

5. Definitions

Critical bleeding – Major haemorrhage that is life threatening and likely to result in the need for massive transfusion

Massive transfusion – In adults, a transfusion of half of one blood volume in 4 hours, or more than one blood volume in 24 hours (adult blood volume is approximately 70mL/kg).

6. Consultation

- General Managers of SLHD facilities
- Trauma services
- SLHD blood banks
- Haematology departments
- Anaesthetic departments
- Intensive care services

7. References and links

Patient Blood Management Guidelines: Module 1 Critical Bleeding Massive Transfusion, NHMRC and NBA, 2011 http://www.nba.gov.au/guidelines/module1/cbmt.pdf

Blood - Management of Fresh Blood Components PD2012_016, NSW Ministry of Health, 2012 http://www0.health.nsw.gov.au/policies/pd/2012/pdf/PD2012_016.pdf

Effects of tranexamic acid on death, vascular occlusive events, and blood transfusion in trauma patients with significant haemorrhage (CRASH-2): a randomised,placebo-controlled trial, CRASH-2 Collaborators, Lancet 2010

Guidelines for the Administration of Blood Components, Australian & New Zealand Society of Blood Transfusion Ltd & Royal College of Nursing Australia, ANZSBT, 2011 http://www.anzsbt.org.au/publications/index.cfm

Guidelines for Pretransfusion Laboratory Practice, 5th ed, Australian & New Zealand Society of Blood Transfusion Ltd, ANZSBT, March 2007
http://www.anzsbt.org.au/publications/documents/PLP_Guidelines_Mar07.pdf

Australian Red Cross Blood Service: http://www.transfusion.com.au/

National Blood Authority: http://www.nba.gov.au

Royal Prince Alfred Hospital – Trauma Service *Trauma Code Crimson Protocol* RPAH_PD2013_019
http://intranet.sswahs.nsw.gov.au/SSWPolicies/pdf/RPA/RPAH_PD2013_019.pdf

Royal Prince Alfred Hospital *Protocol for Emergency Use of O-Negative Blood Stock in the Emergency Department* RPAH_PD2010_028
http://intranet.sswahs.nsw.gov.au/sswpolicies/pdf/rpa/rpah_pd2010_028.pdf

Sydney Local Health District Administration of Blood Products SLHD_PD2013_049, 2013
http://intranet.sswahs.nsw.gov.au/SSWPolicies/pdf/SLHD/SLHD_PD2013_049.pdf

8. **Appendix 1:** MTP flowchart
Appendix 2: Massive Transfusion Protocol Unit Tally

MASSIVE TRANSFUSION PROTOCOL

Medical Team attending bleeding patient

ACTIVATION

Any one of:
Trauma with life-threatening haemorrhage.
Major obstetric, gastrointestinal or surgical bleeding.
Actual or expected ongoing fluid resuscitation after 4 units RBC in ≤ 4 hours.

NOTIFY BLOOD BANK

"Activate MTP"

TESTING

FBC, Coag Screen including Fibrinogen, Biochemistry

Arterial Blood Gasses, including ionised Ca^{++}
Immediately, then
Every 30 – 60 minutes

BLOOD PRODUCTS

RBCs will be issued in sets of 4 units with clotting factors and/or platelets according to blood bank protocol.

Additional platelets and factors may be ordered based on test results or clinical impression.

ADJUNCT MEDICATIONS

Tranexamic Acid indicated in:
Trauma patients requiring blood transfusion within 3 hours of injury
Any other massive transfusion at discretion of treating team.
Dose: 1g over 10 mins then 1g over 8 hours.

rFVIIa
Not routinely indicated
Consider use in consultation with haematologist after attempting to correct fibrinogen, pH, temperature and platelet count.

Haematologist

Liaise with Clinical Team

Information required:
- Age
- Weight
- Estimated blood loss
- Injuries
- Abnormal bleeding
- Hypothemia
- Initial trauma blood results (Haematologist chases results if not yet available)

Advise on administration of
Additional factors and/or platelets
Indication for rFVIIa

Liaise with Laboratory

Liaises regularly with **Blood Bank** to ensure adequate and timely availability of blood products e.g.: pre-emptive thawing of FFP/Cryo.

Liaises with laboratory to obtain blood test results and assists in interpretation of results to advise on blood component support.

GENERAL MANAGEMENT

Aim for:
Temperature > 35°C
pH > 7.2
Ionised Ca^{++} > 1.1 mmol/L
Platelets > 50 x 10^9/L
Fibrinogen > 1.0 g/L
INR ≤ 1.5

Management of bleeding:
Identify cause
Compression, tourniquet, packing
Early intervention:
Surgery
Angiographic embolization
Consider damage-control surgery
Consider cell-salvage

CESSATION OF MASSIVE TRANSFUSION

Notify blood bank promptly once massive transfusion no longer required.

Massive Transfusion Protocol Unit Tally

For Haematologist or Haematology Registrar

Patient Name: ____

MRN:______________________ **Blood Group:** ___________

Name of Medical Officer requesting MTP: ____________________

Date & Time Started: ______/_____/________________am/pm

Red Cells		FFP		Platelets		Cryo		Coags	Advice given
N⁰	**Time**	**N⁰**	**Time**	**N⁰**	**Time**	**N⁰**	**Time**		

Other products

Prothrombinex		Recombinant FVIIa	
Time		Time	
Time		Time	

Policy Directive

Trauma Service :Trauma Code Crimson Protocol

Document No:	RPAH_PD2013_019
Functional Sub-Group:	Clinical Governance
Summary:	This policy provides a guideline for the response to be undertaken in the case of a patient arriving in ED with an acute life threatening haemorrhage. This policy aims to ensure all such cases arrive in the OT within 20 minutes of identification of a life-threatening haemorrhage
National Standard:	Standard 12 Provision of Care
Policy Author:	Director, Trauma Service
Approved by:	General Manager
Publication (Issue) Date:	May 2013
Next Review Date:	May 2016
Replaces Existing Policy:	RPAH_PD2010_027
Previous Review Dates:	2010

Note: Sydney Local Health District (LHD) and South Western Sydney LHD were established on 1 July 2011, with the dissolution of the former Sydney South West Area Health Service (SSWAHS) in January 2011. The former SSWAHS was established on 1 January 2005 with the amalgamation of the former Central Sydney Area Health Service (CSAHS) and the former South Western Sydney Area Health Service (SWSAHS).

In the interim period between 1 January 2011 and the release of specific LHN policies (dated after 1 January 2011) and SLHD (dated after July 2011), the former SSWAHS, CSAHS and SWSAHS policies are applicable to the LHDs as follows:

Where there is a relevant SSWAHS policy, that policy will apply

Where there is no relevant SSWAHS policy, relevant CSAHS policies will apply to Sydney LHD; and relevant SWSAHS policies will apply to South Western Sydney LHD.

Trauma Service -Trauma Code Crimson Protocol

CONTENTS

Royal Prince Alfred Hospital

Trauma Code Crimson Protocol

1. Introduction

The risks addressed by this policy

Clinical Risks

The aims / expected outcome of this policy

To ensure that 100% of patients arrive in the operating theatre within 20 minutes of identifying a life threatening haemorrhage.

2. Policy Statement

This policy outlines the criteria for a code crimson activation and the response to be undertaken following activation.

3. Principles / Guidelines

Criteria

- Acute life-threatening haemorrhage needing immediate surgery
- The Trauma Team will have already been activated
- Code Crimson cannot be activated until the patient has arrived in ED

Activation

- As soon as the decision is made to operate, **Switchboard** is contacted on **222** to activate "**Code Crimson**".

Response

<u>Switchboard</u>

- Sends "Code Crimson" to the Trauma group-page

<u>Medical Trauma Team Leader</u>

- Ensures Primary Survey is completed, including:
    - IV access; specimen sent to Blood Bank; CXR / PXR reviewed
- Ensures Blood Bank have activated "Massive Transfusion Protocol"
- Ensures all team members have completed tasks as listed below

<u>Surgical Registrar</u>

- Contacts consultant surgeon
- Contacts Operating Theatre NUM (50104)

Anaesthetic Registrar

- Contacts consultant anaesthetist and anaesthetic technician

Nursing Trauma Team Leader

- Ensures immediate preparations for patient transfer including:
  - Transport monitor
  - Emergency drugs / equipment
  - Porter (if available)

Blood Bank

- Contacts Trauma Team (50000) to ascertain patient details and injuries
- Activates Massive Transfusion Protocol (SSW_PD2010_011)
- Issues group-specific blood as soon as possible

Operating Theatre NUM

- Ascertains from Trauma Team (50000) patient details and likely surgery (e.g. laparotomy, thoracotomy)
- Prepares theatre, staff and instruments for immediate surgery

Useful Numbers

- Trauma Team Leader: 50000
- ED NUM: 50084
- ED Resuscitation Bay: 55928
- OT NUM: 50104
- Anaesthetic Tech: 20125
- Blood Bank: 58033 or 57831

Cancellation

- Only the consultant surgeon can overturn a Code Crimson activation

4. Performance Measures

- Case by case auditing and monthly review by Trauma Directors at RPAH Trauma Committee Meeting

5. Definitions

CXR: Chest X Ray

IV: Intravenous

NUM: Nursing Unit Manager

OT: Operating Theatre

PXR: Pelvic X Ray

6. References and links

- **Policy Author:** Tim McCulloch Department of Anaesthetics**,** Amanda Stack Trauma CNC, Michael Dinh, Trauma Co-Director; Chris Byrne, Trauma Co-Director; Liz Leonard, Trauma CNC
- **Policy Authorisation:** Department of Trauma Services
- NSW Institute of Trauma and Injury Management
  http://www.itim.nsw.gov.au/go/clinical-resources
- SSW_PD2010_011 Massive Transfusion Protocol (Blood Bank)
  http://intranet.sswahs.nsw.gov.au/SSWPolicies/pdf/SSW_PD2010_011.pdf

2016 Annual Report and Strategic Plan

Department of Trauma Services

Royal Prince Alfred Hospital

Health
Sydney
Local Health District

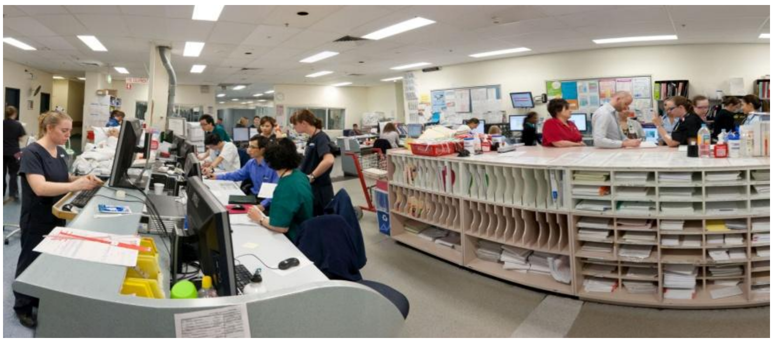
Contents

Forward and Director's message

Royal Prince Alfred Hospital is one of seven adult Major Trauma Centres in NSW under the current State Trauma Plan, with a proud history of trauma and injury management.

The clinical care of injured patients at this hospital currently takes place in the context of one of the busiest Emergency Departments in metropolitan Sydney, underpinned by one of the largest Surgical and Intensive Care Units in Australia.

It remains one of few trauma centres in Australia to rigorously evaluate long term patient outcomes and risk adjusted mortality, evaluate triage protocols against American College of Surgeon benchmarks and the only one to conduct a thorough cost effectiveness evaluation.



Forward and Director’s message

The period between 2010 and 2015 marked an exciting period of activity for the department which saw the formal implementation of Code Crimson, development of trauma networks within Sydney Local Health District, trauma education programs, through to research collaboration, publication and funding grants.

The following report provides a summary of these and other activities undertaken by the Department of Trauma Services at Royal Prince Alfred Hospital between 2010 and 2015 and forms the basis for strategic planning for the next decade of clinical care.

I would like to acknowledge and pay tribute to the dedication and tireless work of the staff in our Trauma Department, without which the data and innovations tabled here would not be possible.

Sincerely,

Michael M Dinh FACEM

Co-Director of Trauma Services RPA

Our mission

- A commitment to delivering high quality, evidence based care to injured patients
- Collaboration with multiple departments and agencies to coordinate clinical, education, research and quality improvement activities
- Improve the outcomes and experience of injured patients we care for
- Remain at the forefront of clinical innovation in trauma care delivery

Our staff

Dr Christopher Byrne – Colorectal Surgeon and Co-Director of Trauma

Dr Michael Dinh – Emergency Physician and Co-Director of Trauma

Dr Jeffrey Petchell – Orthopaedic Surgeon and Co-Director of Trauma

Ms Elizabeth Leonard – Trauma Coordinator and Clinical Nurse Consultant (Mon-Wed) (pictured)

Ms Ebon Smith – Trauma Clinical Nurse Consultant (Thur-Fri)

Mr Kevin Cornwall – District Trauma Liaison and Clinical Nurse Consultant

Our staff

Ms Jameela Truman, Trauma Case Manager (Wed-Sun)

Ms Susan Roncal – Trauma Data Manager

Trauma Surgical Registrar (Dr Cameron Law, pictured Term 1 2016)

Ms Sophie Knott – Trauma Research Nurse (externally funded temporary position)

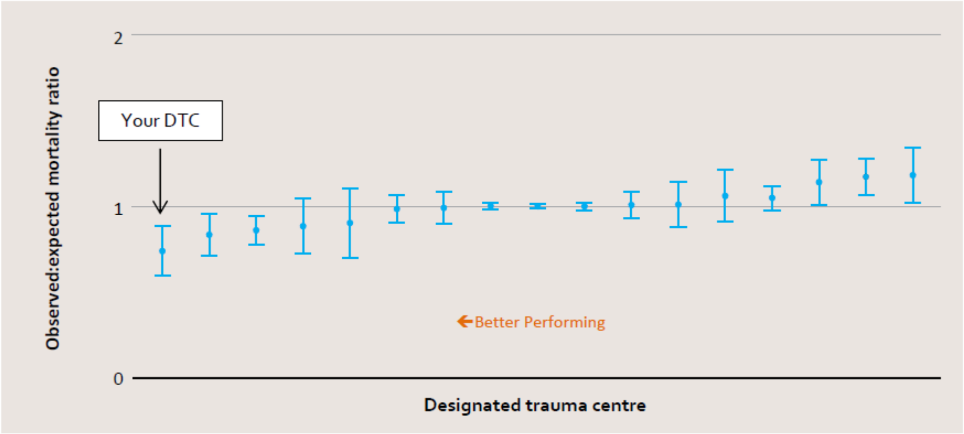
RPA Trauma Committee members 2010-15

- Michael Dinh, Chair
- Christopher Byrne, Trauma
- Jeffrey Petchell, Trauma
- Elizabeth Leonard, Trauma
- Kevin Cornwall, Trauma
- Susan Roncal, Secretariat
- Jeffrey Brennan, Neurosurgery
- Michael Byrom, Cardiothoracic Surgery
- Richard Waugh/Prudence Storer, Radiology
- Fiona David/Catherine Hollow, Radiology
- Timothy Green, Emergency
- Terence Johnson, Emergency
- Nerida Bell, Emergency
- Tim McCulloch, Anaesthetics
- Heike Koezlow, Intensive Care Unit
- Louise Alderson, NSW Ambulance

Our achievements

- Achievements measured by 2010-2015 Strategic Goals
- Major Trauma mortality
- Length of stay and cost-effectiveness
- Interhospital transfers
- Operative and Interventional Procedures
- Educational activities
- Research report

Figure 27 – Caterpillar plot for observed:expected mortality ratio for designated adult trauma centres



Note
*The comparative risk adjustment model adopted was only applied to adults (≥16 years of age).

Reference
Newgard C, Fildes J, Wu L, Hemmila M, Burd R, Neal M, et al. *Methodology and analytic rationale for the American College of Surgeons Trauma Quality Improvement Program*. Journal of the American College of Surgeons. 2013;216(1):145-57

(Above) RPA trauma service benchmarked Nationally amongst our peers, courtesy National Trauma Registry 2013

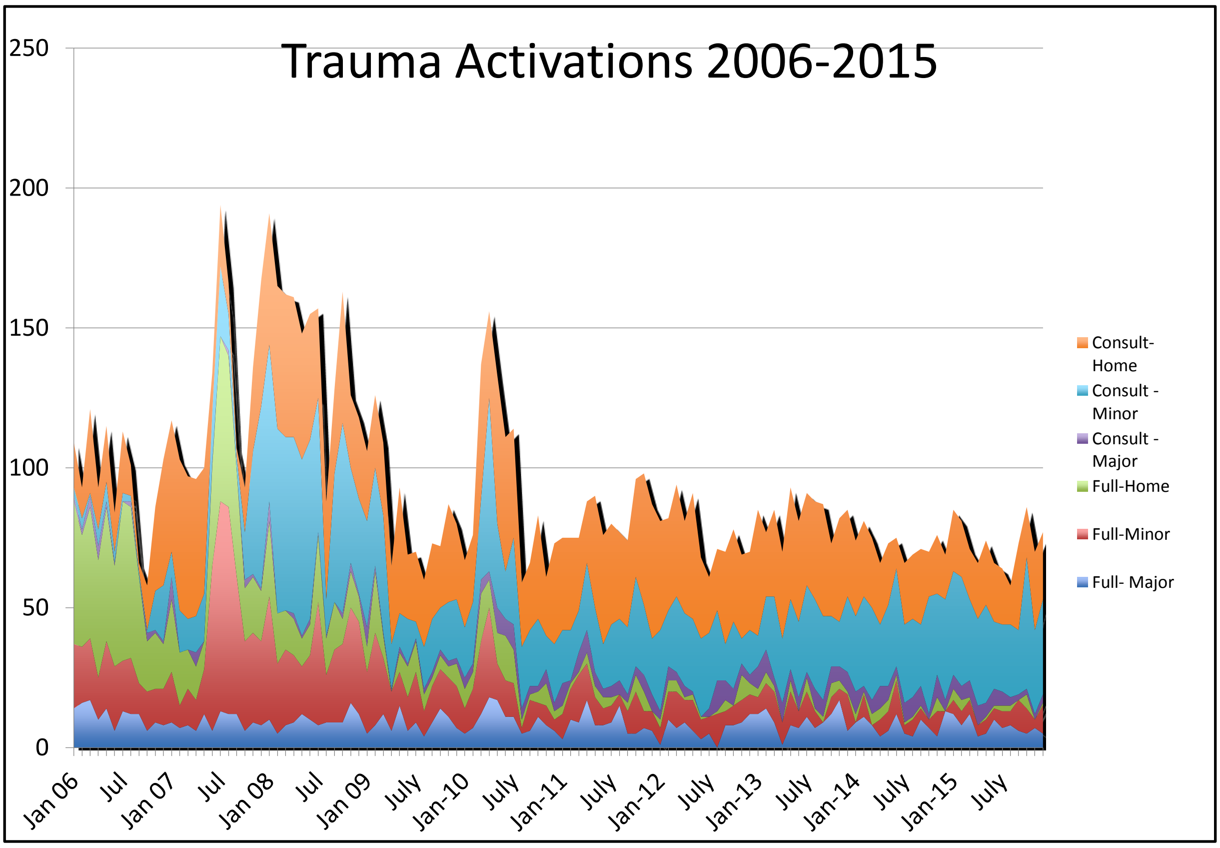
2010-15 Strategic goals

The following strategic goals along with specified targets were outlined in the previous 2009 report

- *A better system of care*
  - Area Trauma Liaison Nurse – employed
  - RPAH Trauma Case Manager – employed
  - Clinical decision support system – trauma app deployed
  - Multidisciplinary grand rounds – initiated 2015
  - ED/Trauma fellowship – yet to be achieved
  - Trauma team training course – Initiated 2010
- *Preventing alcohol related violence*
  - Alcohol use screening in admitted patients – achieved
  - Routine blood ethanol levels in trauma admissions – achieved
  - Submission to Parliamentary Inquiry 2013 which contributed to implementation of "lock-out" laws in inner Sydney
- *Better outcomes management*
  - Follow up clinic for minor injuries – trial initiated 2015
  - Recruitment of trauma physiotherapist – funded 2015-17
- *Research Collaborations*
  - The George Institute for Global Health – achieved
  - NSW Ambulance Service – achieved
  - NSW Ministry of Health – achieved
- Translating evidence and policy to practice
  - Integrated QA and data collection systems – achieved
  - Simulation and education modules - achieved

Trauma team activations

Trauma team activations have been routinely monitored and audited since 2006. All patients requiring trauma team activations in ED are routinely case-managed by the trauma service and clinical and quality assurance data entered into the State-wide trauma registry regardless of injury severity. This translates to the most complete dataset of trauma patients in NSW and facilitates regular system reviews and research based on injury characteristics rather than injury severity.

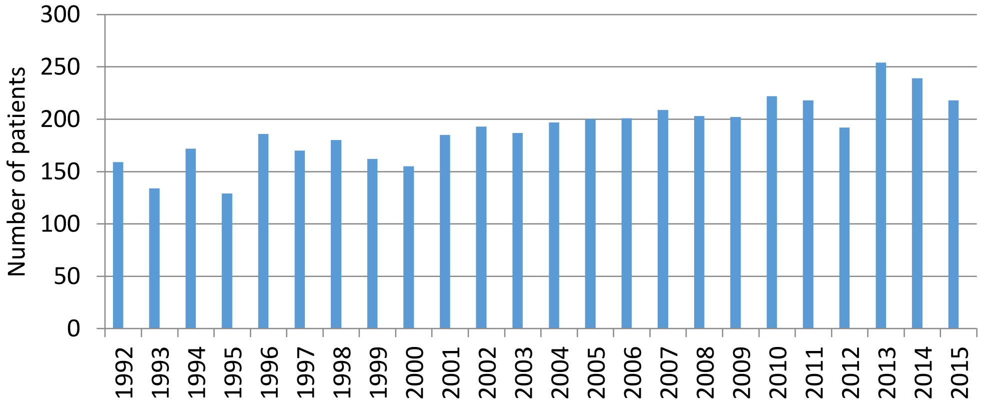


Major Trauma Volume

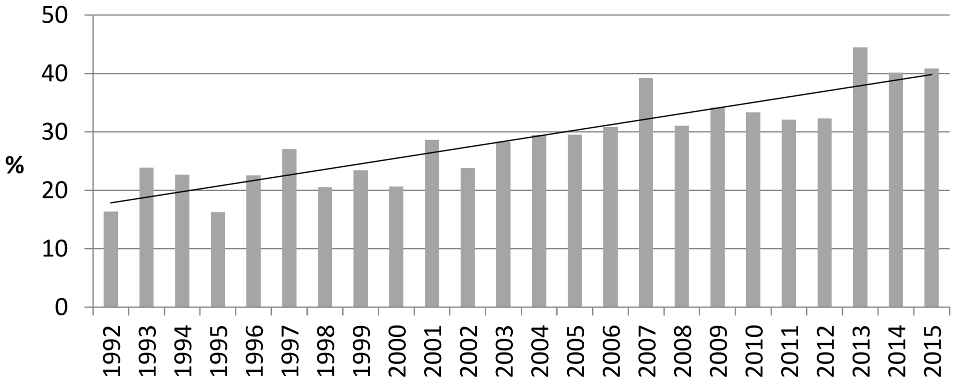
Major Trauma volume (ISS>15) at RPA remains around 200-220 patients per year. A spike in 2013-14 was partly due to the temporary lack of availability of acute cranial surgery at Concord Hospital. In 2014, 104 trauma patients were admitted to the ICU. The mean ICU length of stay was 9.4 days. Of these, 71 patients required intubation with a mean ventilation time of 5.7 days.

Importantly nearly half of all major trauma patients are now aged 65 years or over.

Major trauma volume at RPA



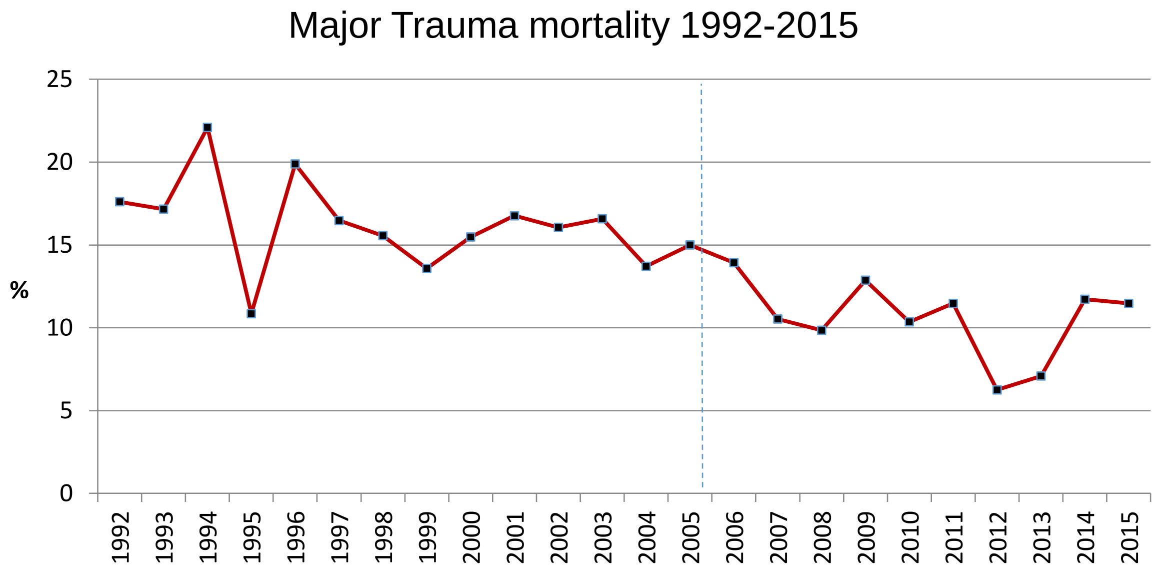
Major trauma patients > 65 years of age



Major Trauma Mortality

Major trauma mortality (ISS>15) has declined since the implementation of formalised trauma triage, team response and education programs at RPA in 2006. Major trauma mortality in 2015 was 11.4% (ISS>15) and 9.4% (ISS>12).

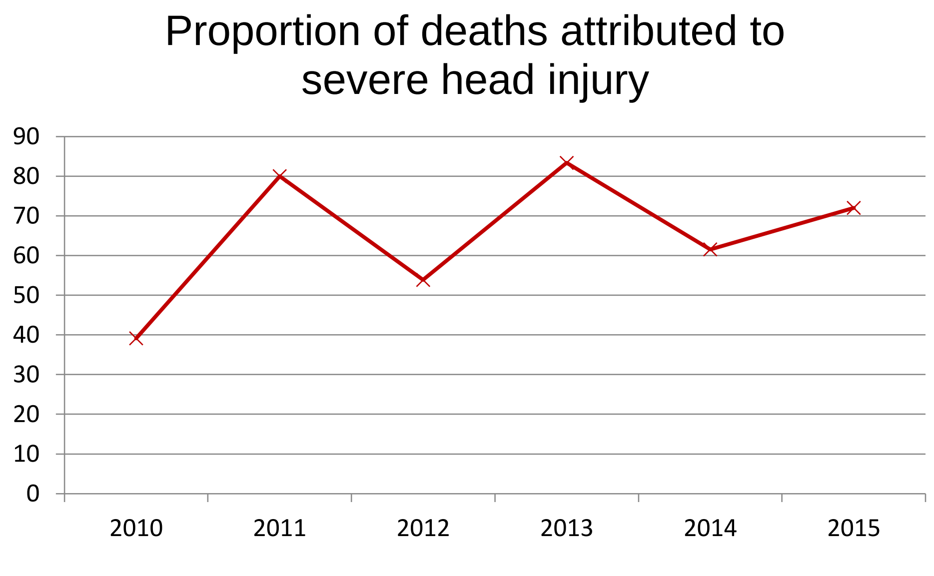
The odds of dying from major trauma continue to be lower by around 33% compared to long term historical averages after adjusting for age differences, injury severity, intensive care use and severe head injury (OR 0.66 95%CI 0.52, 0.83 p=0.0003).



Trauma death review

Between 2010-2015, 130 deaths were reviewed by the RPA Trauma Committee that meets monthly . Of the 130 deaths, 5 (3.8%) were considered potentially avoidable deaths, with two relating to delays in chest drain insertion. As a result, a program of chest trauma education has been initiated by members of the trauma committee which combines theory and simulation training. Management of chest trauma has also been incorporated into trauma team training., and will be a part of simulation modules within the Institute of Academic Surgery.

Currently more than around 80-90% of all trauma deaths are attributable to catastrophic head injury, particularly in the elderly. A review and audit of severe head injury in the elderly is currently under way.



Our policies

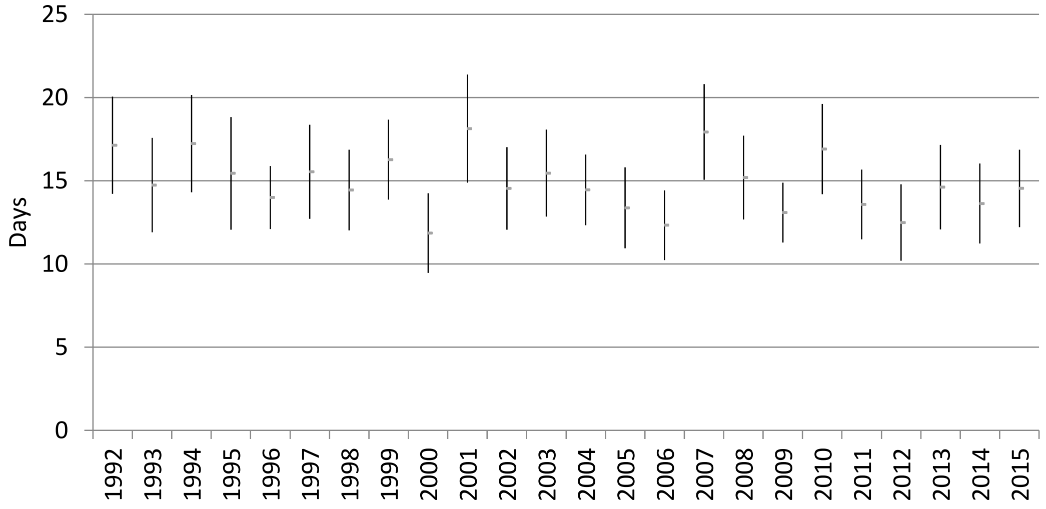
- Trauma team activation protocol
- Mandatory notification protocol
- Code Crimson protocol
- Head injury assessment and management policy
- Cervical spine assessment and imaging policy
- Guideline for thoraco-lumbar spine assessment
- Management of pregnant trauma patients
- Use of interventional radiology in trauma
- Blunt chest pathway
- Trauma admission policy

Acute admitted inpatient length of stay

Length of stay for major trauma patients continues to be around 2 weeks despite the ageing population with more complex medical co-morbidities.

An audit of length of stay in 2013 found that the inclusion of the after-hours case manager resulted in a 25% reduction in average length of stay for minor trauma patients admitted on weekends (Fri-Sun). This was a result of improved coordination of care over the weekends, earlier referrals, tertiary surveys and AW-PTAS testing. This has minimised the backlog of trauma patients that has occurred on Mondays.

Median length of stay patients with ISS>15



Procedures

The number of urgent laparotomies and thoracotomies continues to decline, and this has been mirrored by the rise in interventional and diagnostic angiogram procedures performed by the Department of Radiology. Angio-embolisation is now the definitive procedure of choice for unstable pelvic haematomas and moderate to high grade splenic lacerations.

This has major implications for future trauma models of care and Radiology resources. Importantly, RPA is one of the major centres in Australia for major pelvic surgery and this has flow on effects for training and resourcing of emerging Interventional Radiology techniques in abdominal and pelvic trauma.

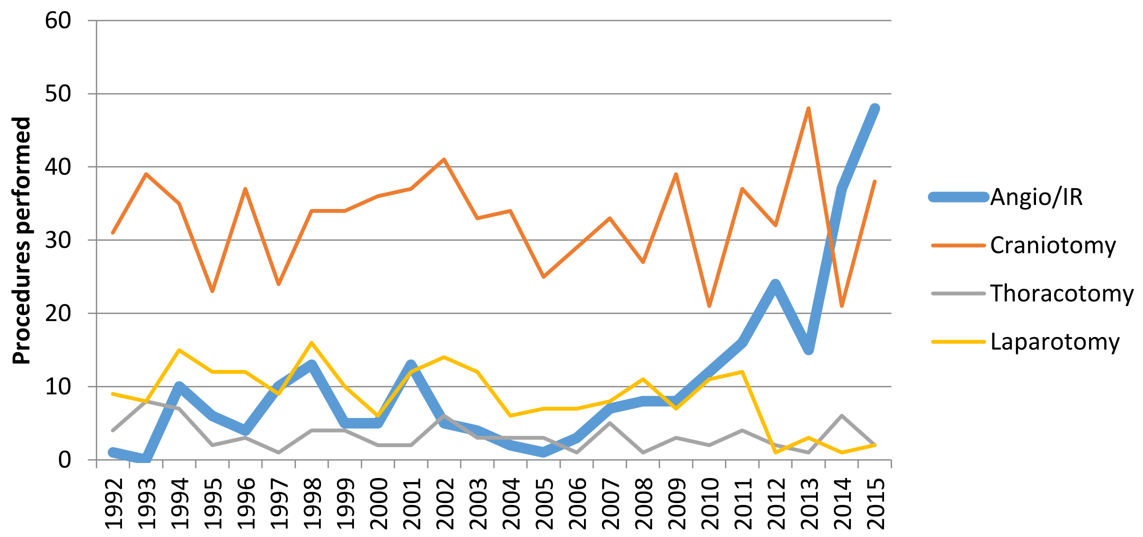


Figure (above) – Procedures performed at RPA on trauma patients by year 1992-2015

Sydney Local Health District

Sydney Local Health District (SLHD) is unique in that includes four hospitals (Royal Prince Alfred, Canterbury, Concord and Balmain Hospitals) that all manage trauma patients to varying degrees. Royal Prince Alfred Hospital is the designated Major Trauma Centre. Concord hospital 10km away has acute Neurosurgery, Thoracic and Interventional Radiology facilities which enables it to see and treat most trauma patients. Concord Hospital (CRGH) is also one of the State's two dedicated Burns Units. Canterbury Hospital (TCH) is a District metropolitan level hospital and Balmain Hospital (BDH) contains dedicated general and geriatric rehabilitation units.

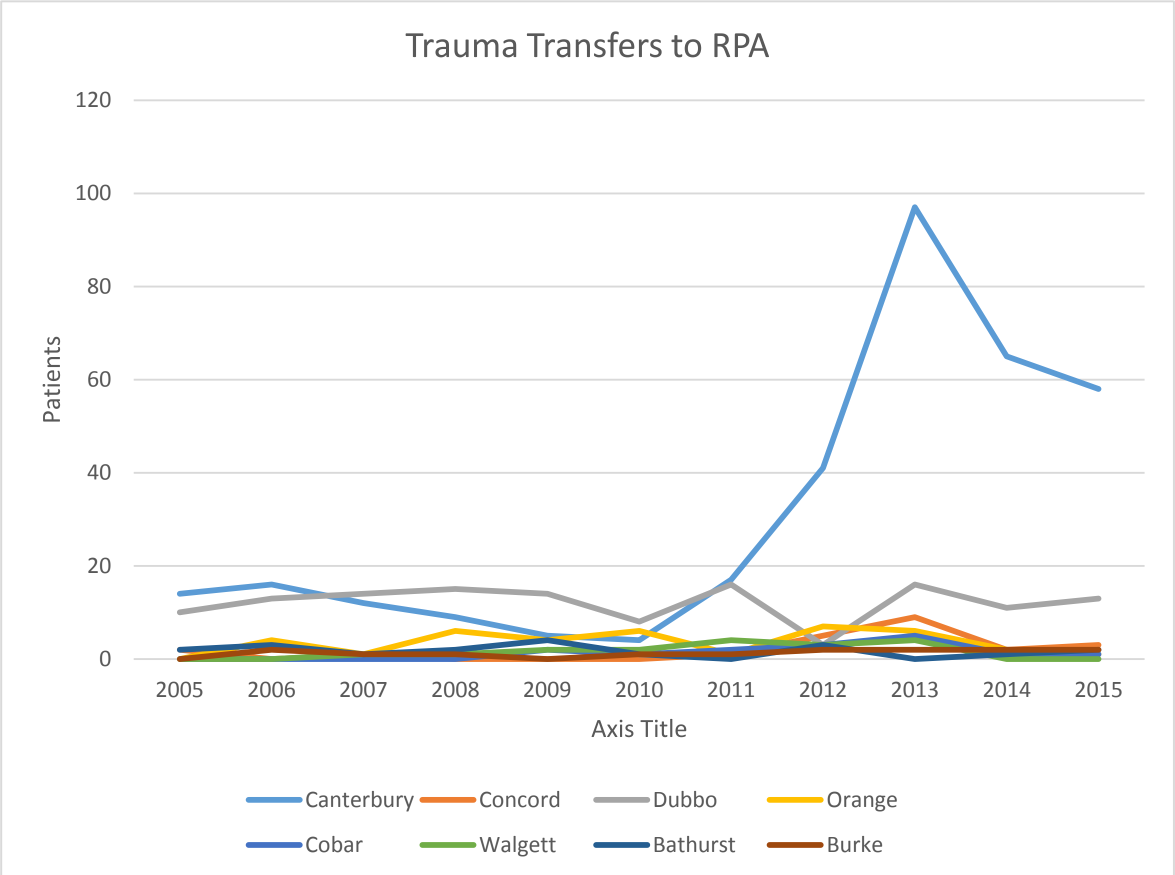
A formal network of trauma referrals within SLHD was begun in 2011 and major trauma (ISS>12) data from all facilities are collected and reported by the District Trauma Liaison CNC. Data from non-Major Trauma Centres are currently not included in State-Wide ITIM Major Trauma reports and the impact of this under-reporting is currently being studied at RPA.

Year	TCH	CRGH (trauma)	CRGH (burns)	BDH	Total
2012	30	23	26	3	82
2013	35	26	24	1	86
2014	31	39	23	0	93
2015	35	53	15*	1	104*

Table (above) – Number of patients with ISS>12 in non-MTC facilities within SLHD. *=incomplete, yet to be finalised

Trauma Transfers

The major sources of inter-hospital trauma transfers are now within Sydney Local health District, as a direct result of the work of the District Trauma Liaison position established in 2011. Referrals from Dubbo, Orange and Greater Western NSW continue in small numbers mainly from direct neurosurgery and upper GIT surgery referrals.



Year	TCH	Concord	Dubbo	Orange	Cobar	Walgett	Bathurst	Burke
2005	14	2	10	0	0	0	2	0
2006	16	0	13	4	0	0	3	2
2007	12	1	14	1	0	1	1	1
2008	9	0	15	6	0	1	2	1
2009	5	0	14	4	2	2	4	0
2010	4	0	8	6	1	2	1	1
2011	17	1	16	1	2	4	0	1
2012	41	5	3	7	3	3	3	2
2013	97	9	16	6	5	4	0	2
2014	65	2	11	2	1	0	1	2
2015	58	3	13	1	1	0	2	2

Cost-effectiveness

A comprehensive cost effectiveness study was undertaken in 2013 to evaluate the trauma department and its value to the hospital. It was conducted in collaboration with partners from Monash University and health economists from Curtin University.

The analysis using retrospective trauma registry data of all major trauma patients (Injury Severity Score >15) presenting after road trauma between 2001 and 2012. The primary outcome was cost per life year gained associated with the intervention period (2007-2012) compared with the pre-intervention period (2001-2006). Incremental costs were represented by all trauma-related funding enhancements undertaken between 2007 and 2010. Risk adjustment for years of life lost was conducted using zero inflated negative binomial regression modelling. All costs were expressed in 2012 Australian dollar values with standard discounting rates used to model best and worst case scenarios.

A total of 876 patients were identified during the study period. The incremental cost of trauma enhancements between 2007 and 2012 totalled $7.91 million, of which $2.86 million (36%) was attributable to road trauma patients. After adjustment for important co-variates the odds of in-hospital mortality reduced by around one half (adjusted OR 0.48, 95% CI 0.27, 0.82 p=0.01). The incremental cost-effectiveness ratio was A$7,600 per life year gained (95% CI A$5524, $19333). This classifies as a low cost intervention by WHO standards.

Education

Royal Prince Alfred Hospital runs a number of medical and nursing trauma education courses for staff within Sydney Local Health District. These include the Trauma Nursing Course conducted quarterly and attended by nurses across the District. The Trauma Team Training course run bimonthly focuses on non-technical skills, team building, communication and simulation and is attended by staff from Anaesthetics, Intensive Care Unit, Emergency and Surgery. Extensive trauma education and training is provided to medical and nursing staff within ED, critical care units and general wards at RPAH. The Trauma Director and CNCs provide trauma related lectures for medical and nursing students at Sydney University.

The annual ITIM education evenings sponsored by the NSW Agency for Clinical Innovation/ITIM are held each year at KPEC auditorium with attendances around 150-200 per year. In addition, a monthly ED grand round presentation and bimonthly hospital wide trauma grand rounds provide opportunities for Consultants and Registrars to discuss cases of interest. All course and sessions are consistently highly rated by attendees. In 2014, a mobile app was deployed with NSW MAA funding to assist with dissemination of trauma policies and guidelines and provide a platform for trauma modules and decision support.

Research and Quality Improvement

The focus of ongoing trauma related research at RPA has been advocacy for injury prevention and public health policy, particularly around mechanisms of injury prevalent in the inner city, such as cycling and assaults. There have been around 20 publications in trauma over the past 4 years ranging from alcohol related harms, helmet use in cyclists through to trauma service evaluation and geriatric trauma. Research into these areas helps set priorities for clinical innovation in the years to come. Priorities for research activities over the next five years will include injury surveillance and the analysis of state-wide data, and implementation of novel models of care such as the trauma interventional radiology position.

There were over 20 peer reviewed trauma publications between 2010-15, two NSW Parliamentary Inquiry submissions and two press releases. Two grants from the MAA have ensured the development of the trauma mobile app at RPA, evaluation of a minor injury trauma clinic, and evaluation of a trauma Radiology fellow as part of the trauma team.

Selected publications

1. Dinh M Roncal S, Bein K, Byrne C. Trend in inner city assaults and relationship to alcohol intoxication. Published EMJ Feb 2013

2. Dinh MM Roncal S, Byrne C. Older patients with severe trauma. Long term trends at an inner city trauma centre. Published ANZ Journal of Surgery 2013

3. Dinh MM McNamara K, Bein K, Roncal S, McBride K, Byrne C. Cost of elderly trauma and increasing trauma severity. Accepted ANZ Journal of Surgery 2013.

4. Leonard EA, Curtis K, and Buckley T. Impact of alcohol on outcomes in hospitalised trauma patients: A literature review. Journal of Trauma Nursing, 2016, 23(1): 103-113.

5. Dinh MM, Stark H, Bein K. Falls from ladders. A profile of injuries at an inner city trauma centre. Published MJA 2012

6. Dinh MM Oliver M, Roncal S, Bein K, Byrne M. Performance of the Ambulance Service of NSW major trauma transport protocol (T1) at an inner city trauma centre. Emerg Med Australas. 2012 Aug;24(4):401-7.

7. **Leonard EA, & Curtis K. Are Australian and New Zealand trauma service resources reflective of the Australasian Trauma Verification Model Resource Criteria? ANZ Journal of Surgery. 2014. Available online February 12. doi: 10.1111/ans.12381**

8. **Bucher L, Leonard E, & Fong J. 2014 Nursing management of emergency care situations in D. Brown and H. Edwards (edns), Lewis' Medical-Surgical Nursing 4e. Sydney, Elsevier.**

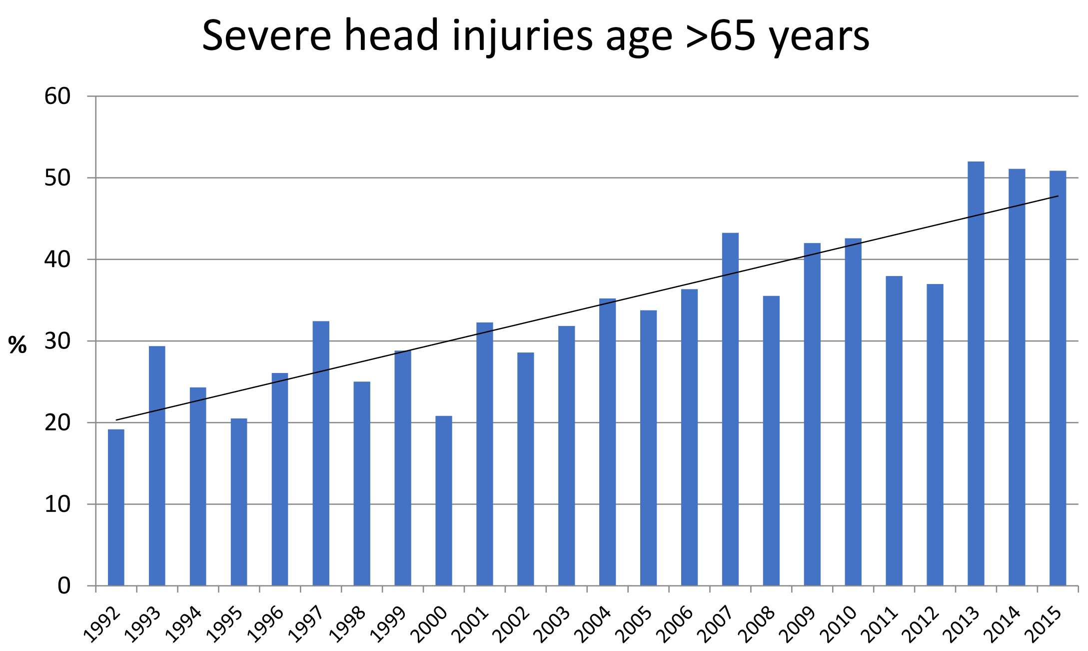
9. Dinh M, Bein K, Roncal S, Byrne C, Petchell J, Brennan J. Redefining the golden hour for severe head injuries. The impact of prehospital times and patient outcomes. Injury. 2013 May;44(5):606-10

Selected publications

10. Hsiao K, Dinh M, Bein K, Byrne C, Saade C, Chi K, Waugh R. Whole body CT scanning in trauma - is there an optimal selection criteria. Emerg Med Australas. 2013 Apr;25(2):182-9
11. Curtis K, Leonard E. Trauma trauma nurse coordinator role in Australia and New Zealand: Demographics, role and professional development. Journal of Trauma Nursing, *2012; 19*(4), 214-220
12. Dinh MM Kastelein C, Bein KJ, Green T, Bautovich T, Ivers R. Use of emergency department syndromic surveillance system to describe the trend in cycling related presentations in Sydney. Accepted Emerg Med Australas. April 2015
13. Gale MS, Muscatello D, Dinh MM, et al. Alcopops, taxation and harm: a segmented time series analysis of emergency department presentations. Published BMC Public Health April 2015
14. Dinh MM[1], Cornwall K, Bein KJ, Gabbe BJ, Tomes BA, Ivers R. Health status and return to work in trauma patients at 3 and 6 months post-discharge: an Australian major trauma centre study. Eur J Trauma Emerg Surg. 2015 Aug 11.
15. Miu J Balogh Z, Curtis K, Dinh M. Ladder Injuries in NSW. Medical Journal of Australia 2016 Published ahead of print

Challenges ahead

- The ageing trauma population – Older trauma patients have more complex acute and chronic management priorities, with an increasingly active population. Challenges include non-operative management of severe head injury, transfer of care, prolonged length of stay, and nursing home related injuries.
- Opportunities for acute surgical training in trauma – a number of factors including non operative trauma management, Interventional Radiology and the dilution of trauma volume due to increased road safety and other major trauma services in NSW have combined to reduce training exposure to acute surgical trauma. This has created the need for innovative models of care and the Institute for Academic Surgery.



Challenges ahead

- Increased hospital activity – increasing general ED and Surgical activity has occurred over the past decade despite stable levels of trauma volume. This creates challenges for patient management due to endemic hospital overcrowding, lack of resuscitation bays and access to Emergency Operating Theatres.

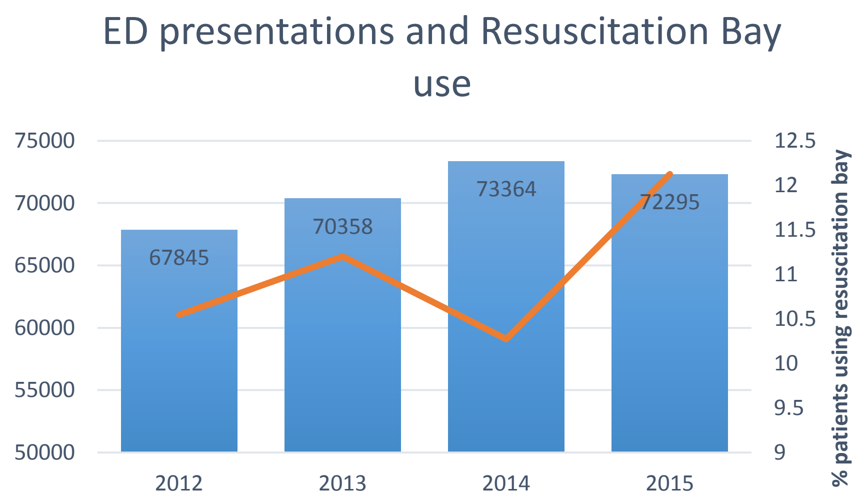


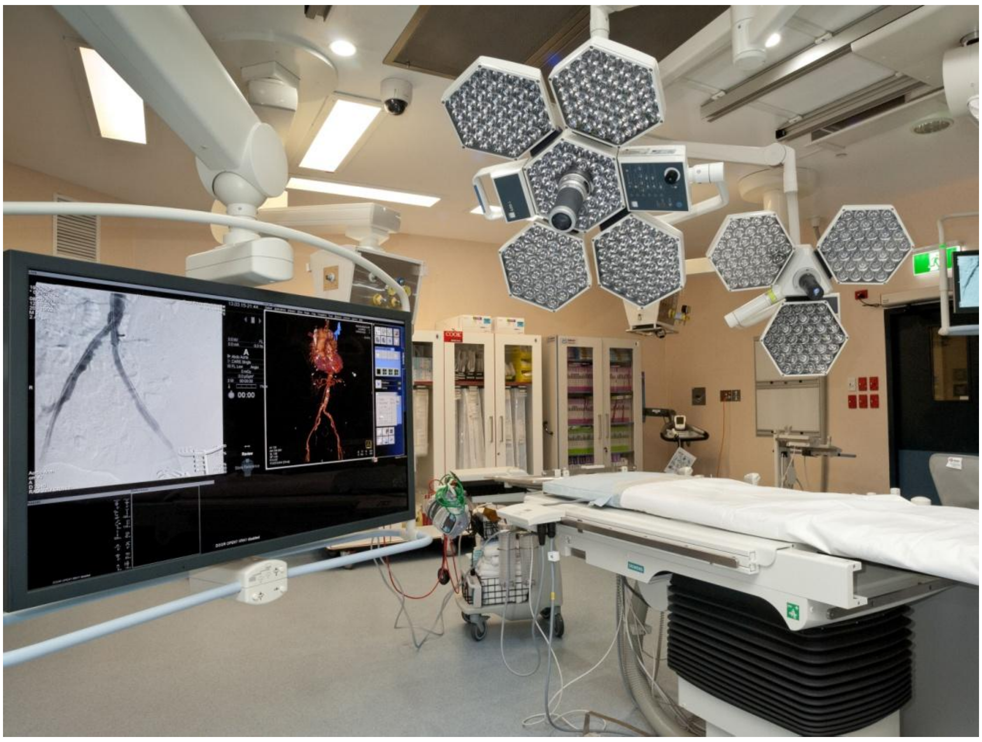
Figure (above) – Emergency Department (ED) presentations and Resuscitation Bay use 2012-15 (Courtesy Ms Sook Lee Chai ED Data Manager)

Strategic Plan 2016-2026

- ✓ *Innovative trauma models of care*
  - ✓ Enhancements for trauma-geriatric service staffed with Consultant Geriatrician and Registrar
  - ✓ Establishment of pre-hospital Code Crimson activation and communication
- ✓ *The rise of Interventional Radiology*
  - ✓ Formal inclusion of Radiology trainee as part of trauma team activation to assist with initial imaging studies and activation of Interventional Radiology resources
  - ✓ Increased capacity for Interventional Radiology and access to Hybrid Theatre and Emergency Theatre
- ✓ *Outcomes measurement research and benchmarking*
  - ✓ Ongoing evaluation of risk adjusted mortality and post discharge outcomes in collaboration with NSW ITIM and the Australian Trauma Registry
  - ✓ Collaboration with established University Research Institutes and NSW Ministry of Health
- ✓ *Formal trauma inter-hospital referral networks*
  - ✓ Expansion of the role of District Trauma Liaison to include inter-hospital networks
- ✓ *Advocate for increased capacity at key pinch points along the patient journey*
  - ✓ Increased Emergency Department Resuscitation areas
  - ✓ Increased Emergency Operating Theatre lists
  - ✓ Improved access to diagnostic CT Radiology

References

- NSW Institute of Trauma and Injury Management. Major Trauma in NSW, 2014: A report from the NSW Trauma Registry. Chatswood Sydney, Agency Clinical Innovation. 2015.
- Alfred Health (2014). Caring for the Severely Injured in Australia: Inaugural Report of the Australian Trauma Registry 2010 to 2012. Alfred Health, Melbourne, Victoria.



(Above) The Professor Geoff White Hybrid Operating Theatre opened in 2013

NSW GOVERNMENT | Health Sydney Local Health District

Injury, Int. J. Care Injured 41 (2010) 470–474

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Prospective evaluation of a two-tiered trauma activation protocol in an Australian major trauma referral hospital

Trudi Davis [a,*], Michael Dinh [a,b], Sue Roncal [b], Chris Byrne [b], Jeffrey Petchell [b], Elizabeth Leonard [b], Amanda Stack [b]

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[b] Department of Trauma Services, Royal Prince Alfred Hospital, Sydney, New South Wales, Australia

ARTICLE INFO

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Trauma team activation
Triage

ABSTRACT

Objective: To evaluate a two-tiered trauma activation protocol in a major trauma referral hospital in Australia.
Methods: A prospective study performed over a 12-month period of all consecutive trauma activations in a major trauma referral hospital. The triage tool assigned patients into two tiers of trauma activation. The full trauma activation was initiated where physiological or anatomical criteria were present. These patients were assessed by a multispecialty trauma team. A consult trauma activation was initiated where only mechanism of injury criteria was present. These patients were assessed by the Emergency Department Registrar and Surgical Registrar. The primary endpoint was major trauma outcome defined as either injury severity score (ISS) greater than 15, requirement for High Dependency Unit or Intensive Care Unit (HDU/ICU) admission, need for urgent operative intervention, or in hospital mortality.
Results: Of 1144 trauma activations, 468 (41%) were full trauma and 676 (59%) were consult trauma activations. The full trauma activation group had a significantly higher proportion of the major trauma outcome (34% vs. 5%, $p < 0.01$) and all 18 patients (2%) who died were in the full trauma activation group. Sensitivity of the triage tool for the major trauma outcome was 83%, specificity was 68%, undertriage was 3% and overtriage was 27%.
Conclusions: The two-tiered trauma activation protocol is effective in identifying patients with major trauma from those with minor trauma. There were no deaths in undertriaged patients.

Introduction

Triage of trauma patients relies on decision tools consisting of physiological, anatomical and mechanism of injury criteria. Many of these have been based on American College of Surgeons Committee on Trauma (ACSCOT) recommendations.[1] Evidence suggests that mechanism of injury criteria has low predictive value for severe injury.[5,7,8,13,17] This leads to overtriage, where minimally injured patients are managed by a full trauma response. The corollary of this is undertriage, where there is a failure to activate the full trauma response for a severely injured patient. ACSCOT states that an overtriage rate of 30–50% is necessary to maintain an undertriage rate of less than 10%.[1]

High levels of overtriage result in unnecessary use of resources, underutilisation of community hospitals participating in the regional trauma system, and escalation of costs of trauma care.[5,6] Efforts to reduce the impact of overtriage led to the development of tiered trauma activation protocols. These systems seek to differentiate the severely injured patients who require a multispecialty trauma response, from the minimally injured patients, for whom an abbreviated trauma response will meet their medical needs. Evidence from the U.S.A. suggests this approach to be safe[2,4,9–12,16] and cost-effective[9,4,15,3] in better matching hospital resources to patients needs.

Multi-tiered trauma systems have been a recent development within Australian hospitals. A 2004 survey of the seven designated major trauma hospitals in the Metropolitan Sydney area found only one hospital using a two-tiered trauma activation protocol.[14] Published experience of Australian tiered trauma activation protocols amounts to a single study published in 1998.[12] This study used a small, convenience sample of patients presenting to their major trauma service between 8 am and 5 pm weekdays for a 6-month period. They found their triage tool adequately distinguished patients with and without major trauma. To our

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Table 1
Triage criteria for full trauma and consult trauma responses.

Full trauma	Consult trauma
Vital signs	*No vital sign or anatomic injury criteria*
SBP < 90 mmHg	*Mechanism*
RR < 10 or >29	Any motor vehicle at high speed (>60 kph)
HR < 50 or >120 bpm	Ejection or rollover or death of vehicle occupant
GCS ≤ 13 or fitting	Pedestrian struck by moving vehicle
Age > 65 with SBP < 100 mmHg or GCS ≤ 14	Bicycle accident >20 kph impact
Major injuries	Fall > 3 m
Any evidence of airway obstruction or compromise	Motorcycle accident with separation from vehicle
Penetrating injury to head, neck or torso	Prolonged extrication time >20 min
Flail chest	
Suspected spinal cord injury	
2 or more long bone fractures	
Multiple body region injuries	
Amputation/crush injury proximal to wrist/ankle	

knowledge, a comprehensive, prospective evaluation of a two-tiered trauma activation protocol in an Australian context has not been published to date.

Objective

This study prospectively evaluated a two-tiered trauma activation protocol active 24 h a day, over a 12-month period in an Australian context. We hypothesised that a two-tiered triage tool distinguishes patients with major trauma outcomes from those with minor trauma.

We evaluated the effectiveness of this protocol by comparing major trauma outcomes in each trauma activation tier and calculating the undertriage and overtriage rates. Using our study cohort we also determined the independent predictors of major trauma outcomes.

Methods

Design

This was a prospective, cohort study over a 12-month period.

Setting

Royal Prince Alfred Hospital (RPAH) is a mixed paediatric and adult major trauma referral hospital under the current New South Wales state trauma plan. Annually it sees approximately 210 patients with an injury severity score (ISS) greater than 15 and admits approximately 3200 minor trauma patients.

Prior to 2007, all trauma patients transported to RPAH who met physiological, anatomical or mechanism of injury criteria were assessed in the Emergency Department (ED) by a multispecialty trauma team.

In late 2007, a two-tiered trauma activation protocol was introduced. Under this system, prehospital and ED triage information was used to determine whether a full trauma team response or an abbreviated trauma response was required (Table 1). An abbreviated response was termed "consult trauma" and consisted of an ED registrar and General Surgical Registrar response (Table 2).

Study population

The study population consisted of all consecutive trauma activations for the period January 1, 2008 to December 31, 2008. The protocol was active 24 h a day. The study group was divided into full trauma activation or consult trauma activation according to triage data and records obtained through hospital switchboard records. Patients transferred to RPAH from other hospitals were excluded.

Outcomes

For the purposes of this study major trauma outcome was defined as a composite end point of either ISS greater than 15, requirement for High Dependency Unit or Intensive Care Unit (HDU/ICU) admission, need for urgent operative intervention (transfer from the ED direct to the operating theatre within 12 h of arrival), or in hospital mortality. This was consistent with previous studies evaluating trauma triage.[2,4,11,12,15,16]

Data collection

Data were collected prospectively and independently of the hospital trauma registry. In addition, information was collected on any trauma patients admitted to hospital without involving a trauma activation. Other variables collected included age, gender, mechanism of injury, vital signs on arrival to the ED, ISS, disposition from the ED and hospital length of stay. The medical records were selectively reviewed for patients with missing data, or to confirm the type of trauma activation. Data collected were stored in Excel format.

Table 2
Team composition for full trauma and consult trauma responses.

Full trauma	Consult trauma
Emergency Department Staff Specialist/Registrar	Emergency Department Staff Specialist/Registrar
Surgical Registrar	Surgical Registrar
Anaesthetics Registrar	Emergency Department Nurse Unit Manager
Intensive Care Unit Registrar	Trauma Clinical Nurse Consultant (in hours only)
Emergency Department Nurse Unit Manager	Radiographer
Operating Theatres Nurse Manager	
Trauma Clinical Nurse Consultant (in hours only)	
General Radiographer and CT Radiographer	
Social worker (in hours only)	

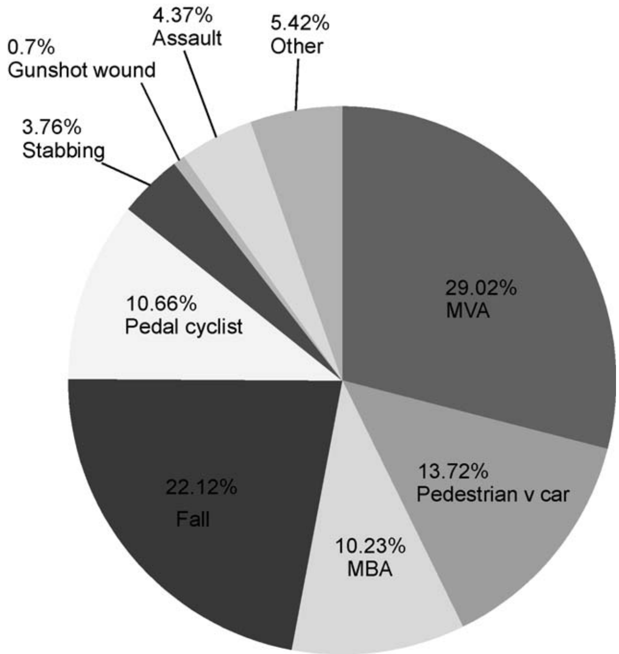

Fig. 1. Mechanism of injury for all trauma activations. MVA, motor vehicle accident; MBA, motor bike accident.

Statistical analysis

A univariate analysis was used to determine the association between trauma activation tier and major trauma outcome. To determine statistical significance, Student's t test assuming equal variance was used for continuous data and the χ^2 test for categorical data. The Mann–Whitney U test was applied to non-parametric data. Continuous data were reported with means and standard deviations or medians with interquartile range (IQR). Statistical significance was set at values of $p < 0.05$ and 95% confidence intervals were reported. Logistic regression was performed to determine unadjusted and adjusted odds ratios (OR) for the major trauma outcome. We used a multivariate model consisting of age, systolic blood pressure (SBP) on presentation, Glasgow Coma Score (GCS) on presentation, ISS and trauma activation tier (full trauma vs. consult trauma).

Sensitivity of the triage tool was defined as the ratio of patients who met the major trauma outcome who received a full trauma activation to the total number of patients who met the major trauma outcome. Specificity was defined as the ratio of patients who did not meet the major trauma outcome who received a consult trauma activation, to the total number of patients who did not meet the major trauma outcome. Undertriage was calculated as the ratio of patients who met the major trauma outcome who received a consult trauma activation to the total number of patients in the cohort. Overtriage was calculated as the number of patients who did not meet the major trauma outcome who received a full trauma activation to the total number of patients in the cohort.

Data analysis was performed with SPSS version 11.0 (Chicago, IL, USA) and Stata version 10.0 (Statacorp, TX, USA) statistical software.

Ethics

Approval for the study was obtained from the Sydney South West Area Health Service (central zone) Human Research Ethics Committee.

Results

During the study period there were 1144 trauma activations. Of these, 468 (41%) were full trauma activations and 676 (59%) were consult trauma activations. The most common mechanism was a motor vehicle accident in 29% of the population (Fig. 1). The mean age of the population was 38.6 $\pm$ 18.9 years (95% CI 37.5–39.7) and 69% were male. There were 130 patients with an ISS greater than 15 (11%). Fifty-eight percent of all trauma patients were discharged home from the ED, 13% required admission to HDU/ICU during their hospital stay, and 5% of patients were sent directly to the operating theatre from the ED. Of the patients with an ISS of less than 16, 46/1013 (4.5%, 95% CI 3.3–5.8%) were admitted to ICU/HDU. The median hospital length of stay for admitted patients was 4 days (IQR 2–10 days). Overall 18 patients died (2%). The median ISS of the patients that died compared to those that survived was 30 (IQR 26–35) vs. 4 (IQR 1–5) ($p < 0.001$).

Univariate analysis of the full trauma activation group compared with consult trauma activation group is presented in Table 3. The mean age was not different between the two groups, however the percentage of males in the full trauma activation group were significantly higher than those of the consult trauma activation group (76% vs. 65%, $p < 0.01$). The full trauma activation group had significantly higher ISS and hospital length of stay. The full trauma activation group had a significantly higher proportion of the major trauma outcome (34% vs. 5%, $p < 0.01$) and all patients who died were from the full trauma activation group.

The unadjusted OR for major trauma outcome in full trauma activations was 10.5 (95% CI 7.0–15.8, $p < 0.001$). Logistic regression was performed on the major trauma outcome to adjust for the effect of age, ISS, GCS and SBP (Table 4). The odds ratios of major trauma outcome were 6.4 (95% CI 4.1–9.95, $p < 0.001$) times higher in patients requiring full trauma activation compared to those in the trauma consult group after adjusting for age, SBP and GCS on arrival. The other significant predictors were ISS and GCS (Table 4).

Based on the data presented in Table 3, sensitivity of the triage tool was 161/193 (83%), specificity was 644/951 (68%), positive

Table 3
Univariate analysis of full trauma patients compared with consult trauma patients.

Category	Full trauma activation		Consult trauma activation		p value
	n = 468	95% CI	n = 676	95% CI	
Age (years)	38.4	36.7–40.1	38.7	37.3–40.1	0.79
Male (%)	355 (76%)	72–80	436 (65%)	61–68	<0.01
ISS (median)	5	1–13	1	1–4	<0.01
Length of stay (median)	5	2–13	4	2–7	0.005
In hospital mortality (%)	18 (4%)	2–6	0	–	<0.01
Emergency surgery (%)	47 (10%)	7–12	5 (0.7%)	0.1–1	<0.01
HDU/ICU (%)	122 (26%)	22–30	23 (3%)	2–5	<0.01
Primary outcome (%)	161 (34%)	30–39	32 (5%)	3–6	<0.01
Discharge from ED (%)	173 (37%)	33–41	490 (72%)	69–76	<0.01

Table 4
Adjusted odds ratios (OR) for primary outcome (ISS > 15, death, admission to ICU and requiring urgent operative intervention (pseudo $R^2 = 0.34$)).

Variable	OR	95% CI	*p* value
Age (years)	1.03	1.01–1.04	<0.001
SBP (mmHg)	1.00	0.99–1.01	0.6
GCS	0.64	0.57–0.72	<0.001
Trauma activation (full vs. consult)	6.40	4.12–10.0	<0.001

predictive value was 161/468 (34%) and negative predictive value was 644/676 (95%). Undertriage was 32/1144 (3%) and overtriage was 307/1144 (27%). Accuracy was 805/1144 (70%).

A total of 32 patients who met the major trauma outcome were undertriaged and received a consult trauma activation. This was a small and heterogeneous group. Thirteen of the 32 patients had sustained head injuries and presented with a GCS of 15, but were found to have intracranial haemorrhages. None of these patients required a craniotomy. Four patients had sustained extremity injuries such as stab wounds and open fractures. These patients met the major trauma outcome as they required operative intervention for explorations or debridement, however they had low ISSs and short hospital length of stay. Six patients sustained injuries in falls or MVAs and presented with normal vital signs, but were found to have significant injuries. None of these patients required urgent operative intervention. Another six patients had significant medical co-morbidities which necessitated HDU/ICU admission, but did not record high ISSs. One patient was admitted to HDU for 1 day for airway observation due to the presence of neck bruising, but did not require intubation. There were two patients who were undertriaged because the triage tool was incorrectly applied by triage staff. Although the small patient numbers make statistical inference inappropriate, the general trend was that undertriaged patients tended to be lesser injured. There was no mortality in undertriaged patients.

A total of 54 patients were identified who were admitted to hospital with trauma-related injury who met the criteria for the major trauma outcome, but did not receive a trauma activation. These patients were identified through the hospital-based trauma registry which collects all injury related admissions. Upon review, 37 (69%) of these did not meet any of the trauma activation criteria. The remaining 17 patients satisfied trauma activation criteria but were misclassified by triage staff. Of the 17 misclassifications, 13 should have been full trauma activations and 4 should have been consult trauma activations based on triage information. If these patients had been correctly triaged this would have increased the number of patients in the consult trauma activation group that met the major trauma outcome to 36. The revised undertriage rate would remain unchanged at 36/1161 (3%).

Discussion

Our results demonstrated that a two-tiered trauma activation protocol was effective in identifying a group of trauma patients more likely to benefit from a multispecialty trauma response. The full trauma activation group was found to be associated with significantly higher rates of the major trauma outcome compared to consult trauma activations. This association was also found to be independent of age, gender, and SBP and GCS on arrival. Our overtriage rate of 27% and undertriage rate of 3% are within the range recommended by the ACSCOT.[1] This has been achieved without any increase in mortality for those lesser injured patients designated for an abbreviated trauma response.

Studies of two-tiered trauma activation protocols from the U.S.A. reported similar results with overtriage rates of 15–25% and undertriage rates of 4–5%.[9,10] The generalisation of these studies to the Australian trauma population is possibly misleading. The Australian trauma population is different with much lower rates of penetrating trauma (4.5% in this study compared with 9–47% in American studies[2,10,11,16]). The Australian trauma system is also different. While many level 1 trauma centres in the U.S.A. are staffed 24 h a day by board-certified trauma surgeons or emergency physicians, Australian trauma teams are generally led by an emergency physician during working hours, and by an emergency registrar overnight. The criteria used in Australian hospitals to assign trauma patients to different tiers of trauma response are more conservative than those used in many American hospitals, where the focus tends to be identifying those patients who require urgent operative intervention or ICU admission only.

There has been only one previous report on a two-tiered trauma activation protocol in an Australian hospital. Ryan et al.[12] reported on 238 trauma patients presenting between 8 am and 5 pm on weekdays to their ED. They used triage criteria for a full trauma activation and outcome criteria defining major trauma which were very similar to our study. Fifty-eight patients (24%) received a full trauma activation. Their reported sensitivity was 65% and specificity was 87%, with an overtriage rate of 10%, and undertriage rate of 8%.

Limitations

We did not record which criteria triggered activation of a trauma response. It is likely that errors were made by triage staff in their application of the triage tool. Ryan et al.[12] found that misapplication of the triage tool increased undertriage and, if applied correctly, undertriage could have been reduced to 3.4%. In addition, our trauma activation protocol allowed for doctor or nurse discretion to upgrade a trauma patient from consult to full trauma activation, regardless of whether the triage activation criteria were met. The frequency of up-triaging was not recorded. A future study may involve more rigorous collection of up-triaging and specific activation criteria to more clearly define the performance of the triage tool. Ryan et al.[12] used very similar activation criteria and outcome measures to our study, but reported a lower sensitivity and higher specificity. It is possible that the difference was due to a less stringent adherence to the triage criteria at our hospital. The overall effect of incorrect application or discretionary upgrade on the performance on the triage tool is not known.

Our choice of primary outcome measure may limit the internal validity of our results. We used ISS greater than 15, requirement for urgent operative intervention or HDU/ICU admission, or death. Long et al.[8] found that trauma-related deaths for patients with an ISS less than or equal to 15 were 1%, but jumped to 20% for those with an ISS greater than 15, suggesting this level represents an appropriate definition of major trauma. The utility of other indicators of severe trauma is less well known. Admission to HDU/ICU is dependent upon local practices which may be highly variable and may not reflect injury severity. Indicators of major trauma used in prior studies include ICU and hospital length of stay. However, these are also subject to variation from factors not associated with injury severity, such as availability of ward beds and waiting times for home support services.

The criteria chosen to activate a trauma response were heterogeneous across different studies, with Australian triage criteria more conservative than those used in American hospitals. It is expected that trauma activation criteria would differ between countries and even between hospitals in the same region due to variability in trauma workload and ability to mount a trauma response. Variability with respect to trauma activation criteria has been reported within the Metropolitan Sydney region.[14] This must be remembered when considering the external validity of each study's results. In our study 32 severely injured patients were undertriaged by our trauma triage criteria. Another 37 severely injured patients were 'missed' by our trauma triage criteria. This finding reflects the need for ongoing trauma audit at individual institutions to continually assess and revise the performance of the institution's trauma triage criteria.

Conclusion

A two-tiered trauma activation protocol is effective for use within the context of an Australian Metropolitan major trauma referral hospital as a mechanism to better match the facilities resources with the patient's needs. Future research into the management of the large and minimally injured group of patients who meet mechanism of injury criteria only may contribute to further enhancing the efficient use of hospital resources.

Conflict of interest

There are no declared conflicts of interest.

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Trauma Service 2009

Service Overview

Table of Contents

Welcome to the Department of Trauma Services at Royal Prince Alfred Hospital.

As a designated Trauma Centre, our mission is to provide the highest level of care for our injured patients and provide clinical leadership at a hospital and area health level.

Trauma management involves;
Clinical care – from prehospital transfer, emergency department resuscitation, definitive care, post operative care to rehabilitation
Communication within the RPAH Trauma Team
Coordination of different subspecialties and health facilities
Collaboration with key stakeholders including hospital management, area health services and the NSW Institute of Trauma and Injury Management

Trauma management is often very stressful but we are here to help you. There are regular education sessions and trauma meetings. It is important that you communicate with us if there are any issues relating to patient care or your learning objectives.

We hope you find this rewarding and educational.
Sincerely,

Dr Chris Byrne
Dr Michael Dinh
Dr Jeff Petchell
Liz Leonard Trauma CNC
Amanda Stack Trauma CNC
Sue Roncal Data Manager
Royal Prince Alfred Hospital Department of Trauma Services

Introduction

The term 'trauma' refers to patients who have sustained physical injury. Injury is defined as unintentional or intentional damage to the body resulting from acute exposure to thermal, mechanical, electrical or chemical energy or from the absence of such essentials as heat or oxygen (Royal College of Surgeons England, 2000). The spectrum of trauma encompasses patients who have sustained minor injuries that can be quickly treated at local emergency departments, through to major (or severe trauma) which usually require hospital admission and access to specialised resources.

In Australia, injury remains a leading cause of death, illness, and disability accounting for 5.8% of all deaths (ITIM NSW Health 2004).

The NSW Trauma System

The current trauma system is based on a networked system of hospitals, designated to provide different levels of trauma service in metropolitan, urban and rural settings. It includes a pre- hospital component, where trauma patients are triaged by Ambulance Officers according to specified criteria. This ensures that the patient is transported to the most appropriate hospital for their actual and potential injuries.

The NSW Trauma System is not a stand-alone system, but part of the spectrum of acute and critical care services and is consistent with the overall framework provided by the NSW Critical Care Plans (metropolitan and rural), following the same statewide referral networks.

Major Trauma Services

Major Trauma Services are Tertiary care facilities, which provide all clinical specialties including acute Neurosurgical, acute Cardio-thoracic and Trauma Rehabilitation services. The facility also requires a full Diagnostic Service, both interventional and non-interventional. Seriously injured patients who require intensive coordinated and integrated clinical management will form the pivotal group for treatment within the Major Trauma Service.

The major trauma service is required to demonstrate consultation, leadership, research and education to its network hospitals. It is also required to utilise an integrated, prospective Performance Improvement Program, which supports excellence in clinical management (ITIM NSW Health 2005).

Six metropolitan Major Trauma Services currently provide adult trauma services in NSW. These are:

- Liverpool Hospital
- Royal Prince Alfred Hospital
- Royal North Shore Hospital
- St George Hospital
- St Vincent's Hospital
- Westmead Hospital

Each of these Major Trauma Services is aligned with a Regional Trauma Service (Metropolitan and Rural). These hospitals are capable of providing a high level of care to the trauma patient, but are not able to provide the range of services required within the Major Trauma Service. The regional institution may provide initial assessment, stabilisation and definitive care. They initiate patient transfer to the Major Trauma Service when a patient requires unavailable services.

Clinical Profile

The management of trauma patients requires an organised multidisciplinary team approach. The multidisciplinary team is developed, led and evaluated by a Trauma Service, comprised of the Trauma Medical Director, Trauma Nurse Coordinator, Trauma Registrar, Trauma Data Manager and Administrative support. The Trauma Service is responsible for the care rendered by the multidisciplinary team.

Hospital referrals

Primary

In 2007, Royal Prince Alfred Hospital treated 217 major traumas (ISS>15). Of these, 156 (%) of patients were direct from scene. Forty-one patients (%) were transferred from another health facility. RPAH reviewed a total of 2899 minor trauma patients in 2007 (ISS<15) (RPAH Data Registry, 2008)

Rural

RPAH is a major trauma referral hospital for Metropolitan Sydney, Rural NSW and overseas (Noumea, Fiji). In 2007, RPAH received 40 major trauma patients from Rural NSW and 18 major trauma patients from the Sydney Metropolitan Area.

Demographics

For admitted patients, males comprised of 76.6% of and females 23.4% of admissions. The most common mechanism of injury included;fall<1metre (33%),pedesdrian (14.4%), motor vehicle collision (12%), followed by assault (10.9%), by motor vehicle and motor bike collision (5.5%).

Fifty-three per cent of these patients required admission to the intensive care unit (106), with an average length of stay of 6.41 days. The average length of hospital stay was 12.68 days (ITIM, 2007)

Performance Improvement

To maintain our standards in trauma care the Trauma Service aims to implement and evaluate care based on Key Performance I

Trauma Service
Key Performance Indicators (KPIs)

Pre-hospital Phase	*Resuscitative Care Phase*	*Definitive Care Phase*
Scene time ?20mins (ISS>15)	*Trauma Team Activation	Laparotomy ? 2 hours (ISS>15)
*CDA case sheet present (ISS>15)	*Trauma Team response	Craniotomy within 4hrs injury (ISS>15)
Intubation GCS < 9 within 10 minutes	*Trauma sheet present and complete (ISS>15)	Debridement long bone # ? 6hrs (ISS>15)
Bat call according to CDA criteria	CXR within 10minutes of arrival	Angiography within 2 hrs
	Blood prior to exceeding 2000mls	Temperature documented upon arrival ICU
	Intubation GCS <9 within 10 minutes	No re-presentation to ED ? 72hrs
	All intravenous fluids warmed (ISS>15)	No unplanned presentation to ICU within 48hrs (ISS>15)
	Temperature on all patients within 10minutes of arrival	Tertiary Survey within 24hrs (ISS>15)
	CT scan ? 1 hour (ISS>15)	Missed injury within 48hrs (ISS>15)
	Joint dislocation reduced ? 1hr	Thrombo-embolic prophylaxis
	Documentation of C-spine clearance	Missed cervical spine fracture

The following activities have been developed to assist in meeting KPI's and improving trauma management at RPAH.

- All trauma patients are admitted under the Trauma Consultant of the day for a period 24hrs. When appropriate, the patient is then transferred to the definitive team. The Trauma Service ensures consultation with specialist teams to ensure best care and involvement of sub-specialties.
- Clinical teaching and orientation, which is multidisciplinary in nature.
- The weekly Trauma Radiology meeting facilitates learning and the identification of actual or potential missed injuries.
- Our registry and data collection system allows the collection of various KPI's relating to the delivery of trauma care at the hospital and referral networks.
- The Trauma Service Quality Improvement Program involves the identification of actual and potential problems pertaining to trauma management, appropriate follow-up and action to ensure best patient outcomes.
- The Trauma Service facilitates the Hospital Trauma Committee which is directly responsible for the process of hospital trauma care
- All trauma deaths are reviewed by the committee at the monthly Trauma Morbidity & Mortality (M&M) Meeting
- Monthly Emergency Department (ED) Trauma M&M provides important clinical practice feedback, education and improvement to staff working within the ED.

Staff Profile

The roles of the Trauma Service members are highlighted to demonstrate their involvement within the trauma system and its patients.

Trauma Director

The Director provides the leadership required of a trauma service to function within the Hospital and wider Area Health Service, as well as the State-wide Trauma Network. Leads the multidisciplinary activities of the trauma system. The Director continually evaluates the delivery of trauma care and is responsible for the development and implementation of protocols and clinical practice guidelines, for optimal trauma management.

Trauma Clinical Nurse Consultant (CNC)

The CNC works with the Trauma Director to ensure patients receive appropriate care. The Trauma CNC coordinates the day-to-day hospital activities required of the trauma service. This involves monitoring patient care throughout the hospital, identifying actual and potential complications in patient care and making recommendations for change. The CNC is also responsible for the development and implementation of protocols for trauma management. The CNC also possesses a clinical role in assessment and management of the trauma patient throughout all stages in patient care.

The Trauma CNC is a resource person for all members of staff and the community regarding trauma management. This role includes a strong emphasis on clinical education and training.

Trauma Data Manager

The Data Manager is responsible for collecting all data relating to trauma management within RPAH. Data is required to provide evidence regarding the effectiveness of the Injury Management Program. Data collated can be utilised to review trauma management at a State level. This allows for the identification of trends / differences across the Sydney Metropolitan area. Data is also required to measure patient information, clinical performance indicators and system performance. This allows for review of practice and implementation of change.

Administrative support is essential to all of the activities of the Trauma Service within a Hospital

Trauma Registrar

A dedicated Trauma Registrar works within the Trauma Service between the hours of 0800-1700hrs Monday to Friday. This position rotates every four months. The Registrar is responsible for the day-to-day clinical medical activities of the Trauma Service, under the consultation of the Trauma Director and Clinical Nurse Consultant. The Registrar carries the hospital trauma page and is required to respond to all trauma calls as a priority. The registrar is also required to conduct tertiary surveys on major trauma patients and those who have met trauma call criteria on admission to hospital.

Outside these hours, the Surgical Registrar on call is required to respond to all trauma calls

Individual service roles

Emergency Department

Observe and review the appropriate management of trauma patient taking particular note of the following:

- Ensure appropriate trauma response is activated as per hospital policy
- Ensure trauma response personnel attend the ED in a timely manner and conduct the trauma in a professional manner
- Perform a role in the trauma team as required
- Provide appropriate leadership and direction regarding investigations and interventions
- Ensure the primary and secondary surveys are performed in timely manner
- Confirm that a plan of care is established and documentation of definitive management is provided
- Ensure transferred to relevant unit within appropriate time frame
- Identify issues in patient management, consult with senior clinicians in a timely manner and provide feedback as required

Radiology Department

CT scan/angiography

- Consult with the Radiology Department as required to ensure appropriate response to trauma call
- Determine need for early radiology series
- Review process to ensure CT performed within appropriate time frame
- Ensure patient haemodynamically stable prior to transport to CT scan
- Ensure results reviewed by senior medical officer/s and decision made regarding ongoing treatment.

Operating Theatre (OT)

- Observe patient progress to operating theatres within appropriate time
- Review the process of notification to OT if case of imminent patient arrival
- Review documentation within the OT (temperature and IV fluids)

Intensive Care Unit

- Attend multidisciplinary trauma rounds of all major trauma patients twice weekly
- Perform Tertiary Survey on ALL patients in ICU within 24hrs
- Ensure daily rounds of all ICU trauma patients to monitor clinical progress, oversee coordination of clinical teams, liaising with the ICU medical and nursing staff to ensure systematic, comprehensive care
- Provide data collection on the ICU component of care
- Identify variances in management that require addressing within the hospital trauma service
- Identify any "system" problems that may effect patient outcomes and make recommendations for change.
- Provide formal and informal in-service to nursing staff regarding trauma management

High Dependency Unit

- Perform daily rounds of all HDU trauma patients to monitor clinical progress and ensure coordination of clinical teams
- Liaise with the ward resident, nursing staff and Trauma Director to ensure comprehensive care.

General Wards

- Identify trauma patients admitted and ensure coordination of care
- Identify trauma patient situated in "out of service" wards
- Collect data on identified trauma patients
- Liaise with nursing staff to ensure care is coordinated and identify issues that may affect patient outcomes
- Identify any "system" problems and make recommendations for change
- Provide education on the nursing management of trauma patients.

Trauma Education

Session	Venue	Dates	Coordinator/contact
Trauma Ground Rounds	John Greenaway Lecture Theatre	Monthly Dates TBA	Michael Dinh Trauma CNC
Trauma Radiology Rounds	Radiology Department	Monday am	Jeff Petchell Radiologist TBA
Weekly Trauma Case Review	KPEC 4.2	Wednesday am	Trauma Director Trauma CNC
Nursing in-service	Emergency Department Wards/ICU	Weekly As requested	Trauma CNC Trauma CNC
Trauma Nursing Course 4 Day	RPAH/Liverpool	May-June Sept-Oct	Trauma CNC
2 Day Trauma Course	RPAH	2 courses Intranet	Trauma CNC
C-spine Workshop	RPAH	Quarterly	Trauma CNC
C-spine management teaching and accreditations	RPAH 10W2, 10W1, 8W2	As required	Trauma CNC
Trauma Team Training Course	RNSH Simulation Centre	Quarterly SSWAHS to attend yearly as delegated	Trauma CNC on faculty
RPAH Trauma Team Training Course (modified-4hr)	RPAH Emergency Department	Dates to be confirmed	Trauma CNC

Trauma Meetings

Meeting	Venue	Dates	Representative
RPAH Morbidity and Mortality Meeting	RPAH Level 11 Boardroom	2nd Tues of every month	Trauma Service Emergency Service Intensive Care Service Neurosurgical Service Cardiothoracic Service Radiology NSW Ambulance Service
Disaster Committee Meeting	RPAH	Quarterly	Trauma Director Trauma CNC
NSW Trauma Services Meeting	Institute of Trauma management Macquarie Hospital	Bimonthly	Trauma CNC Trauma Director
NSW Trauma Education Meeting	Institute of Trauma management Macquarie Hospital	Bimonthly	Trauma CNC
NSW Death Review Meeting	Institute of Trauma management Macquarie Hospital	Bimonthly	Trauma CNC

Trauma Policies

The trauma service has a number of policies in place that support the patient care process though initial presentation to rehabilitation. These policies have been developed in consultation with relevant key stakeholders and have been implemented by the Hospital Trauma Committee

ROYAL PRINCE ALFRED HOSPITAL
TRAUMA TEAM ACTIVATION PROTOCOL

Injury is a common cause of presentation to the Emergency Department. The purpose of trauma activation criteria is to accurately triage those injured patients who benefit from a coordinated team response. Such patients include those with;

- Potentially life threatening injuries
- Multiple or complex injuries
- Injuries requiring urgent or immediate surgery

The RPAH Trauma Team is activated by dialing 222 for;

1. Pre-hospital notification of direct or transferred trauma patient via "bat phone"
2. Patients identified by the triage nurse as satisfying full trauma team activation criteria
3. Doctor or Registered Nurse review of patient in the ED who subsequently meets full trauma or Trauma consult criteria

Staff notified as part of the RPAH Trauma Team activation includes:

1. Operating Theatres Nurse Manager 1
2. Emergency Department Staff Specialist/ Registrar
3. Surgical Registrar
4. Anaesthetics Registrar
5. Intensive Care Unit Registrar
6. Trauma CNC (during hours)
7. Emergency Department Nurse Unit Manager
8. Radiographer
9. Social Worker (in hours)

CRITERIA FOR FULL TRAUMA TEAM ACTIVATION (MANDATORY)

Any <u>one</u> of the following criteria in a trauma patient mandates full trauma team activation (dial 222).

VITAL SIGNS

- Systolic Blood Pressure <90mmHg
- Respiratory rate <10 or >29
- Heart rate <50 or >120bpm
- Glasgow Coma Score 13 or less or fitting
- Age over 65 with Systolic Blood Pressure <100mmHg or Glasgow Coma Score 14 or less

MAJOR INJURIES

- Any evidence of airway obstruction or compromise
- Penetrating injury to head, neck or torso
- Flail chest
- Suspected spinal cord injury
- 2 or more long bone fractures
- Multiple body region injuries
- Traumatic amputation or crush injury to limb proximal to wrist or ankle
- Burn greater than 20% BSA associated with trauma
- At the discretion of upon review by any Doctor or Registered Nurse
- Trauma transfer from another hospital

TRAUMA CONSULT (OPTIONAL)

If a patient meets the following mechanism criteria without major injury or vitals signs abnormalities, the Triage nurse must contact the ED Consultant or ED Registrar on ext 54705 to determine whether a trauma consult needs to be activated;

MECHANISM

- Any motor vehicle accident at high speed (>60km/hr)
- Ejection or rollover or death of vehicle occupant
- Pedestrian struck by moving vehicle
- Bicycle accident >20km/hr impact
- Fall >3m
- Motorcycle accident resulting in separation from vehicle
- Prolonged extrication time > 20 minutes

Particularly in those patients with multiple minor injuries that require admission under the Trauma Service. A Trauma consult may be subsequently upgraded to Full Trauma Team activation if the patients condition changes or the injuries are deemed to be serious enough. (Dial 222 and request Trauma consult)

DIRECT NOTIFICATION OF SURGEON ON CALL AND STAFF EMERGENCY PHYSICIAN BY TRAUMA TEAM LEADER

- Systolic blood pressure< 90mmHg confirmed in resuscitation bay
- Administration of blood products in resuscitation bay
- Arrival of 3 or more simultaneous trauma patients
- Consensus relating to treatment or definitive care not able to be met
- Any gunshot wound to the torso/neck

SPECIAL CONSIDERATIONS

- Cardiothoracic Registrar must be informed upon prehospital notification or arrival to ED of penetrating chest injuries. The Cardiothoracic Registrar must be present on patient arrival. Cardiothoracic Consultant must be informed if Registrar cannot attend.
- Neurosurgical Registrar or Consultant must be informed within 15 minutes of arrival, of severe head injuries (GCS <9) or head injuries requiring intubation.
- Obstetrics and Gynaecology Registrar or Consultant must be informed upon prehospital notification or ED arrival of trauma patients who are pregnant >20 weeks gestation
- Paediatric Surgeon on call and Paediatric Registrar (during hours) must be informed of all paediatric traumas (age<16 years)

ROYAL PRINCE ALFRED HOSPITAL
PROTOCOL FOR INTER-HOSPITAL TRANSFER OF TRAUMA PATIENTS

All inter-hospital transfers of trauma patients to Royal Prince Alfred Hospital require initial assessment in the emergency department unless they are transferred from a Trauma Centre designated by the Institute of Trauma and Injury Management.

Trauma Centres currently include the following hospitals:

- Royal North Shore Hospital
- John Hunter Hospital
- Liverpool Hospital
- St George Hospital
- Westmead Hospital
- St Vincent's Hospital

Requests for admission:
Requests for admission are accepted by the ICU Consultant. The ICU team should then notify the following:

- Trauma Registrar
- Emergency department admitting officer
- Any subspecialty registrar

Initial assessment of the trauma patient in the emergency department will require Trauma Team Activation or Trauma Registrar review (according to Trauma Team Activation Protocol).

Direct transfer to an intensive care unit:
Patients may be transferred directly to the ICU/NICU/CICU if the patient is a direct transfer from a Trauma Centre and have been have been completely "worked up". In this case, the ICU Consultant will have been notified by the retrieval team and care accepted. The ICU team will notify the Trauma Registrar of the transfer.

Upon arrival to the ICU contact the following:
Trauma Registrar 8am-5pm, Mon-Fri
Surgical Registrar 5pm-8am, Mon-Fri & 24hrs Sat-Sun for assessment.

Exception:
Delayed direct transfer of the trauma patient to ICU may be required i.e. patient requires specialised ventilation or further surgery. In this case, consultation is required between ICU/ED admitting Consultant

TRAUMA TEAM LEADER ORIENTATION

The Trauma Team Leader plays a pivotal role in the initial assessment and stabilization of the trauma patient. This person prioritises, coordinates and communicates from the moment of prehospital notification until transfer to definitive care. At RPAH, this role is usually assigned to the Emergency Staff Specialist or Senior Emergency Registrar. In situations where senior ED staff are unavailable, the role may be delegated to the General Surgical Registrar or Intensive Care Registrar. If the Trauma Surgeon on call is present in the resuscitation bay, the Trauma Team Leader role is automatically assigned to them

The Role of the Trauma Team Leader

- Ensures adequate trauma team and resuscitation bay preparation
- Anticipates necessary resources
- Coordinates and delegates the activities of the trauma team
- Identifies and prioritises injuries
- Communicates these priorities to all members of the Trauma Team
- Expedites transfer to either Operating Theatres or CT
- Maintains order and crowd control.
- Reviews all imaging and complete documentation
- Handover patient to the Surgical team and/or ICU
- Appraisal and feedback of Trauma Team performance

An excellent trauma team leader has the following qualities

- A strong leader – everyone in the room should sense that you are in charge
- Excellent communication skills
- An understanding of trauma resuscitation and priorities
- Maintains a sense of urgency in the team
- Knows when to call for help
- Manages both the patient and the trauma team

The Clock

The clock is important in trauma management. You should decide within 10 minutes whether the patient requires urgent transfer to the operating theatres and communicated this decision to the team. All the essential tasks of the trauma drill should be completed by the 30minute mark and the patient should essentially be waiting for transfer with portable monitoring by the 45 minute mark. If imaging or operating theatres are busy resulting in delays beyond the 90 minute mark, this should be documented clearly in the notes.

Critical issues

The trauma team leader should familiarize themselves with the initial assessment and definitive approach to the following trauma scenarios

1. Severe head injuries
2. Hypotension
3. Unstable pelvic fractures
4. Cervical spine imaging and clearance
5. Blunt chest and abdominal injuries
6. Open fractures
7. Penetrating torso/neck injuries

These are the situations that consistently result in delays and mismanagement in any trauma system.

Trauma Team Leader Checklist

1. Trauma Team activated
2. Trauma Surgeon notified if appropriate criteria met (SBP<90mmHg in resuscitation bay, GSW torso, more than 2 simultaneous trauma activations)
3. All Trauma Team members wearing blue gowns, gloves and eye protection
4. TTL wearing lead gown
5. Team members appropriately identified and introduced
6. TTL briefs Trauma Team of expected patient details and anticipated course of action
7. Patient transferred to the trauma bed on arrival
8. TTL takes handover from ambulance staff in MIST format (< 60 seconds allowed)
9. Primary Survey commences immediately and monitoring equipment attached
10. Asks for results of the Primary Survey from individual Trauma Team members
11. TTL determines a management plan and contacts relevant people – radiology, OT, blood bank
12. Takes results of the secondary survey from the Surgical Registrar and communicates the patient summary and definitive management plan to ALL Trauma Team members
13. Instructs the Radiographer to complete necessary Trauma X ray series and performs a FAST during this time
14. Above completed within 30 minutes of arrival time
15. Determines when individual team members can leave
16. Explains management plans to patient and family members
17. X rays completed and checked
18. Documentation of Trauma Sheet complete
19. Appropriate supportive care and adjuncts are given –e.g. analgesia, ADT, antibiotics
20. Patient prepared for transfer to Radiology Department or definitive care

AMBULANCE HANDOVER

The Trauma Team Leader is responsible for ensuring rapid and smooth handovers from Ambulance staff to the Trauma Team. The following principles apply:

The handover must be conveyed in the MIST format

A. Mechanism and time of Injury
B. Injuries
C. Vital signs

Treatments and Interventions including IV fluid volumes

1. The handover must take less than 60 seconds.
2. The handover is directed to the Trauma Team Leader who is responsible for recording and acting on this information. All Trauma Team members are to stand back and listen to the handover unless otherwise instructed by the Trauma Team Leader.
3. The Primary Survey takes precedence over information gathering. If the patient is deemed to be unstable, the Trauma Team Leader should defer patient information handover until completion of the Primary Survey.

TRAUMA TEAM ROLES AND RESPONSIBILITIES

UNIVERSAL PRECAUTIONS

All Trauma Team members must wear at a minimum

1. Blue gown
2. Gloves
3. Face mask or goggle

NURSING TEAM LEADER

Roles and Responsibilities

- Allocates nursing team member roles according to skill and experience
- Takes patient handover with the Trauma Team Leader
- Ensures all Trauma Team members are identified with a written label
- Contact Nurse Manager in OT (#80901) if urgent surgery anticipated
- Liaise with Trauma Team Leader regarding patient management priorities
- Liaise with Social Worker and family members
- Documents Nursing notes

AIRWAY DOCTOR (Anaesthetics Registrar/Intensive Care Registar)

Roles and Responsibilities

- Ensures necessary equipment is available
- Ensures airway patency and protection
- Ensures oxygen is placed on patient
- Coordinates endotracheal intubation
- Orders ventilation parameters
- Gastric tube
- Communicates the airway findings to the TTL during the primary survey
- Communicates what is required for definitive airway management to the TTL
- Takes the head of the bed during log roll
- Communicates all relevant findings to the TTL at the completion of the log roll and when appropriate asks the TTL when they can leave the resuscitation bay
- If a potentially unstable patient is being transferred (patient intubated, SBP<90mmHg, urgent transfer to OT), the airway doctor MUST remain with the patient.

AIRWAY NURSE

Roles and responsibilities

- Checks oxygen, bag valve mask and suction are functioning prior to patient arrival
- Checks airway trolley, laryngoscopes, appropriate sized ETT, introducers and bougie are present
- Prepare medications necessary for intubation
- Assists with endotracheal intubation when required
- Post intubation care, capnography and portable ventilators/monitoring equipment prepared for patient transfer
- Ensure oxygen tank ready for patient transfer

BREATHING/PROCEDURE DOCTOR (Surgical Registrar)

Roles and Responsibilities

- Checks adequacy of ventilation (assess chest wall movements, air entry and oxygenation)
- Performs decompression of tension pneumothorax and insertion of chest drain
- Checks CXR
- Assists with joint splinting and pelvic immobilization/reduction
- Performs disability assessment – GCS, pupillary response and gross peripheral neurological examination
- Conducts secondary survey
- Communicates with TTL regarding patient summary and management plan
- Makes necessary arrangements for urgent transfer to OT including notification of Trauma Surgeon on call
- Makes necessary arrangements to admit the patient
- Checks all imaging studies and liaises with the TTL regarding results
- Performs tertiary survey

PROCEDURE NURSE

- The procedure nurse must have good working knowledge of the resuscitation bay and equipment

- *Roles and Responsibilities*

- Cut off patient clothes
- Assisting with cricoid pressure or in line cervical immobilisation
- Obtaining necessary equipment and medications for procedures
- In dwelling urinary catheter
- Wound care and tetanus immunisation
- Assist with log roll and transfer of patient

Sets up and assists with the following procedures
- Chest tubes
- Limb splinting
- Wound repair

CIRCULATION DOCTOR (ICU Registrar, ED Registrar or ED RMO)

Roles and Responsibilities

- Ensures adequate intravenous access
- Checks blood pressure, pulse and capillary refill
- X match and other trauma bloods ordered and sent
- Assists with pelvic stabilization and compression of external haemorrhage
- Warmed IV fluids bolus is given if necessary and a running tally of IV fluid amount kept
- Blood products are given early if hypotensive
- Assists with procedures
- Assist with log roll
- Administer medications required for intubation

- Communicate findings and IV fluid response to the TTL

CIRCULATION NURSE

Roles and Responsibilities

- Set up monitoring devices – pulse oximetry, ECG electrodes and blood pressure monitoring
- Ensure intravenous lines are primed and going through fluid warmer
- Running tally of intravenous fluid requirements and communicates this to the Trauma Team Leader
- Assist with intravenous access procedures
- Measures patient temperature

COMMON PITFALLS IN THE TRAUMA TEAM

1. Not wearing adequate protective equipment
2. Failing to communicate the Primary and Secondary Survey findings to the Trauma Team Leader
3. Trauma Team Leaders failing to communicate specific patient management priorities to Trauma Team members
4. Not directing specific requests through the Trauma Team Leader – this creates confusion and duplication. The Trauma Team Leader assumes direct responsibility for patient management and therefore all investigations and interventions must be conveyed and approved by this person. This ensures a coordinated trauma response.
5. Trauma Team Leader who becomes involved in procedures and loses sight of the overall trauma objectives and priorities
6. Failing to focus on haemorrhage control and persisting with fluid resuscitation
7. Allowing the patient to become hypothermic

CONCLUSION

Managing severely injured patients can be stressful and appear chaotic. Knowing what the priorities are and communicating well can improve both patient outcomes and team satisfaction. Trauma management is never easy but a good trauma team makes it LOOK easy

TRAUMA DRILL FOR TRAUMA TEAM LEADERS

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Royal Prince Alfred Hospital

December 2007

CONTENTS

1. INTRODUCTION AND BACKGROUND

Effective and timely management of trauma patients requires the coordinated response of a trauma team. Central to the trauma team response is the role of the trauma team leader (TTL). The TTL coordinates delegates and prioritizes essential tasks in the resuscitation room and decides on a plan of action based on these priorities. In situations where there is more than one trauma patient, the TTL is responsible for prioritizing and overseeing management in the context of available resources in the emergency department.

Royal Prince Alfred Hospital is a Major Trauma Centre – this means that we are expected to provide nothing less than the best trauma care in the country – any deviation from the highest standards is considered a failure of the system. At present Emergency Department (ED) Registrars and Consultants are expected to assume the role of TTL at all hours. This means that the experiences and expertise can be highly variable. The role of the Department of Trauma Services and in particular this manual is to ensure that despite this variability, the standard of trauma assessment and management in the first few hours remains of the highest quality.

With this in mind the most important priority for the ED trainee faced with a major trauma is to know when to call for assistance and what resources to mobilize. When it comes to complex decision making there is no substitute for consultant level experience. A mandatory requirement for all Level One trauma centres is the presence of consultant on call coverage 24 hours a day. The expectation is that both the Trauma Surgeon on call and the Emergency Consultant on call will provide the necessary expertise and support in the event of any major trauma.

The following is a guideline for the conduct of all trauma activations and a compendium of common problems encountered in a question and answer format. It has been compiled through personal experiences with trauma as well as feedback from other trauma resuscitations. It represents the minimum standard and it is expected that all ED trainees commit this to memory and regularly rehearse trauma scenarios using the template provided below. It is not a substitute for a basic understanding of trauma management which can be obtained by attending an ATLS course. It is also not devised for the sake of standardizing care – Trauma remains the single biggest cause of mortality and morbidity in patients under the age of 45 years. Therefore we owe it to ourselves and the patients we serve to provide exceptional and uncompromising trauma care.

KEY PRIORITIES AND PREREQUISITES

Essential prerequisites and resources for Emergency Trauma Team Leader

- Attendance at trauma clinical meetings and teaching sessions
- RPAH trauma service overview booklet
- Liverpool hospital trauma manual
- Relevant chapters in Tintinalli, Rosen or other Emergency texts
- EMST / ATLS equivalent or at least intent to attend in the next 12 months
- Participation in trauma CME
- Discussions with Trauma Directors or Trauma CNC

Key Priorities for trauma team leaders
- Know **when to call** for senior assistance
- **Coordinate** the team response
- Recognise and treat **haemodynamic instability**
- Know when to take a trauma patient straight to theatres
- Know **what to image** and when to obtain imaging
- **Documentation** and follow up results
- Maintain a sense of **urgency** in the team

The Clock

The clock is a vital part of trauma resuscitation. All trauma patients should have the primary survey and necessary imaging (CXR, Pelvis X ray and FAST) completed within 15 minutes of arrival. The need for urgent interventions or further imaging should also be decided by the 15 minute mark (earlier if the patient is haemodynamically unstable). By 30 minute mark the patient should have had a secondary survey and be ready for transfer to CT or definitive care (at the latest). Key performance indicators for trauma are as follows;
Intubation for severe head injury (GCS<8) within 10 minutes of arrival
Head CT for severe head injury within 1 hour of arrival
Laparotomy for abdominal trauma within 2 hours of injury time
Craniotomy within 4 hours of injury time
Open fracture reduction within 6 hours of injury time

Communication

Communication is an important aspect of any team and the most important part of your role as trauma team leader. Some helpful tips to ensure effective communication before and during traumas include;

- **Introduce** yourself to team
- **Know when to call** for senior assistance
- Get **MIST** handover from ambulance staff
- **Delegate** essential tasks according to team roles
- Ask for formal **primary survey** summary
- Ask for formal **secondary survey** summary
- Communicate with nursing staff and surgical registrar what the **management plan** will be

Trauma Roles (see Trauma Team Roles Document)

Trauma Team Leader – coordination and communication
Nursing Team Leader – coordinate nursing roles
Anaesthetics registrar – airway doctor
ICU registrar – circulation and backup airway and procedure doctor
Surgical Registrar – breathing and procedures
Airway nurse
Circulation/Procedure nurse
Radiographer

2. THE TRAUMA DRILL

Trauma Activation Protocol
There are currently two tiers of trauma activation at RPAH; a full trauma team activation and trauma consult activation. The latter occurs when a single patient satisfies only one mechanism of injury criteria. The criteria are posted in triage, resuscitation bay, trauma assessment form and the service booklet. The criteria used to activate the trauma needs to be documented on the trauma assessment form

A trauma can be activated by prehospital notification, identification at triage or on subsequent assessment in the ED by doctor or nurse. If a patient who does not initially meet criteria at triage subsequently meets criteria on clinical assessment due to changing clinical circumstances, then a trauma must be activated and the patient moved to the resuscitation bay.

In addition certain circumstances require the immediate notification of the Trauma Surgeon on call at the time the following is determined;

- SBP <90mmHg measured in the resuscitation bay
- Requiring blood products during resuscitation
- Gunshot wound to the torso or neck
- Three or more simultaneous trauma activations
- Consensus not achieved with regards to definitive care or ongoing management

PREPARATION
How to prepare after the BAT call?
- Ensure Trauma page is activated
- Decide who to notify
- Resuscitation bay cleared
- Airway trolley, chest drain tray and IV access trolley ready
- Protective equipment – blue impervious gown, lead gown (for TTL and airway doctor), face mask or goggles and gloves are the minimum
- Arrange active warming measures such as Bair Hugger and fluid warmer
- Team members have identified themselves

Who do I call during preparation phase?

- **Trauma surgeon on call** and ED consultant on call – if there are three or more simultaneous trauma activations from the same incident or otherwise, if the incident involved a gunshot wound to the torso or neck and if there was prehospital arrest at scene with recovery of vital signs
- **Operating theatres** – any penetrating injury to the torso is likely to need urgent operative intervention, any patient with a prehospital SBP <90mmHg associated with multiple injuries
- **Cardiothoracic registrar** – any penetrating chest wound
- **Blood bank** – any patient with a prehospital SBP<90mmHg associated with multiple injuries. In these situations inform them that extra O negative blood is required.
- **Radiology registrar** – significant mechanism (e.g. pedestrian struck at high speed or by heavy vehicle, motorcyclist at high speed, significant fall > 3m or history of major injuries at scene) If the radiology registrar is not on site, it may be reasonable to defer this until the primary survey is complete
- **Security** – if there has been a history of violent or psychotic behaviour associated with the trauma (involved in altercation with others etc.)

When do I take the ambulance handover?

The ambulance handover should take no more than 1 minute. If the patient has airway compromise, respiratory distress or hypotension, then the patient should be transferred immediately onto the trolley before handover. During handover, the team should stand back and listen to the prehospital handover. However this does not take precedence over the initial primary survey in patients with airway compromise, respiratory distress or hypotension. In these circumstances, the handover should commence after the primary survey and directed between the TTL, ambulance officer and nursing team leader.

The following information should be clarified

1. Time of injury
2. Mechanism of injury
3. Injuries identified
4. Vital signs at scene
5. Treatment provided including the volume of intravenous fluid

The handover should take no more than 60 seconds and the TTL should interrupt the handover at any stage if it is felt that the patient's condition is better served by immediate transfer.

Where does the TTL stand?
The TTL stands at the end of the bed with the trauma sheet, one eye on the clock and the other on the trauma itself. Ideally you should have the cordless phone in your hand. It is imperative that you avoid getting involved in procedures during resuscitation. You must focus your attention on important decisions and communication. The TTL also remains with the team until the completion of the secondary survey. If there are more urgent matters to attend or assessment is complete, the TTL must handover the ongoing management plan to the General Surgical Registrar

THE PRIMARY SURVEY

Priorities in the primary survey

Seek and treat life threatening ABC conditions
Perform resuscitative measures
Determine need for urgent operative or angiographic intervention and summon the appropriate expertise

The most important priority of the Primary Survey is to seek and treat conditions that pose an immediate threat to airway, breathing and circulation. These are;

•*Airway obstruction* – patient not breathing due to arrest or upper airway obstruction. The airway can be cleared at this stage either through inspection or simple manouvers such as jaw thrust, oropharyngeal airway and or suction devices. Maintain cervical spine immobilization until secondary survey.

•*Tension pneumothorax* – indicated by respiratory distress, tracheal deviation and hypotension. This is treated with needle decompression and high flow oxygen

•*Haemorrhagic shock* – this can be temporized with large bore intravenous access and IV fluid and blood products. The causes of massive bleeding and shock that can be identified during the primary survey are external haemorrhage, massive haemothorax, grossly unstable pelvic fracture, tension pneumothorax, long bone fractures and pericardial tamponade and haemoperitoneum.

This can be ascertained and treated by the trauma team within the first 2 minutes using good ABC technique.

The second priority is to perform resuscitative measures related to airway breathing and circulation. These should be performed over the next 5 minutes

- *Airway* – definitive airway
- *Breathing* – Chest X ray, chest tube(s)
- *Circulation* – direct pressure, stapling of bleeding scalp wounds, Pelvic X ray, FAST, pelvic sling, arrangements for operating theatres, resuscitative thoracotomy

As soon as urgent intervention is required, all team members are to wear lead gowns – in these situations, CXR and pelvic X rays are part of the resuscitation and must not be delayed merely because urgent procedures are being performed.

The third priority of the primary survey is to decide whether the patient needs to go for urgent definitive management and to notify the appropriate senior staff. The operative or angiographic approach to a grossly unstable trauma patient should be determined by yourself and Trauma Surgeon on call by the 10-15 minute mark. Some important clues during the primary survey include;

➢ *Chest injury* – penetrating injury, gross deformity, haemothorax, widened mediastinum = thoracotomy

➢ *Abdomen* – penetrating injury, distension, tenderness and bruising = laparotomy

➢ *Pelvis* – grossly unstable, scrotal or perineal haematoma = pelvic embolisation or external fixation

Conduct of the Primary Survey

1. TTL gets brief history from ambulance – time of injury, mechanism, vital signs and interventions are all that are required at this stage. Ambulance personnel are required to stay in resuscitation bay to provide further information and documentation at least until the completion of the primary survey.

2. Nurse – cuts off patient clothing and places monitoring leads

3. Airway (Anaesthetics registrar) – ask patient to open mouth and say “ah”. If required, place an oropharyngeal airway, ask for assistance for in line stabilization and prepare for airway intubation. If airway assessed and clear, place oxygen via non rebreather on and assist with placing monitoring devices on and getting intravenous access. If indicated place a hard collar on.

4. Breathing (surgical registrar) – if conscious, ask the patient “is there any trouble breathing?” Check tracheal position and air entry. Assess need for relief of tension pneumothorax or urgent chest drain insertion. Ask for oxygen saturations and give supplemental oxygen.

5. Circulation (ICU registrar or ED doctor and circulation nurse) Inserts 16G IV cannula x 2 into antecubital fossa, draws trauma bloods including blood alcohol (pedestrian, driver, cyclist) and place blood pressure cuff and other monitoring devices – monitoring leads and oximetry. If peripheral access is difficult in a potentially unstable patient, central vein access is obtained by ICU or Anaesthetics registrar. Any external source of bleeding is controlled with direct pressure dressings and the pelvis is assessed for stability. If the pelvis is grossly unstable, a bed sheet is wrapped tightly around the pelvic ring and tied. If there are any indications of shock, an intravenous crystalloid bolus is given with reassessment with view to early blood transfusion. If there are no indications of shock then only maintenance fluids are ordered.

6. A brief directed neurological assessment is made by the Anaesthetics Registrar or Surgical Registrar. This is directed at Glasgow coma score, pupillary reaction to light and gross peripheral motor function.

At completion of this (2 minute mark), the TTL will ask for airway, breathing and circulation summary. The TTL then directs any definitive resuscitative measures required. While definitive measures are being taken (intravenous access, chest X ray, intubation, chest drains, FAST), the following questions should be asked;

THE IMPORTANT QUESTIONS IN TRAUMA

The four most important questions to ask yourself at this point are;

1. Is this patient haemodynamically stable?
2. Who do I need to call?
3. Does this patient need urgent operative or interventional radiology management and if so how fast should I get them there?
4. What do I need to scan?

Is this patient haemodynamically unstable?

1. A patient who looks **pale and sweaty** is unstable, regardless of vital signs.
2. **Frank hypotension** - SBP measured in resuscitation bay <90mmHg
3. **Persistent tachycardia** >130 bpm
4. Requiring **any blood products** during resuscitation

A patient who is haemodynamically unstable has ongoing haemorrhage until proven otherwise. Steps must be taken to identify and correct the source of haemorrhage as quickly as possible. Once the patient is unstable, the amount of fluid or blood products used does not change outcome. Do not assume that normalization of vital signs with fluid resuscitation means that the patient is stable. In addition, the lethal triad of hypothermia, coagulopathy and acidosis should be considered and prevented.

Grades of haemorrhagic shock

This is based on current ATLS guidelines but has been modified to reflect what actually happens in the resuscitation bay

Grade 1 – minimal haemorrhage, normal mental state and vital signs.

Grade 2 – mild haemorrhage, anxious with tachycardia. Systolic BP maintained Expect normalization with single fluid bolus

Grade 3 – moderate haemorrhage, anxious confused and sweaty, tachycardia with drop in blood pressure. Requires recurrent fluid bolus and blood products

Grade 4 – severe haemorrhage, lethargic grey and diaphoretic, systolic BP <90mmHg (often <80mmHg) with no response to fluid bolus. Must go straight to OT or interventional angiography. Transport with blood products ready

Moribund – extreme blood loss, peri-arrest SBP<70mmHg, only minutes to go before patient arrests. Patient goes straight to OT but prepare for resuscitative thoracotomy. Get blood products, IV access, chest tubes and thoracotomy set ready

Who do I need to call?

If measured SBP <90mmHg at any point in the resuscitation, requiring blood products, three or more simultaneous trauma activations or a gunshot wound to the torso, both the Trauma Surgeon on call and ED consultant on call must be notified now. If the patient clearly needs blood products urgently, then blood bank needs to be notified and O negative units called for. An urgent X match for 6 units of packed cells and 4 units of FFP should be sent. Porters should be notified early of any imminent transfers to OT.

If CT scanning is indicated, then the CT registrar should also be notified at this point. This expedites imaging process and allows it to be done at the hour mark.

Does this patient need to go directly to OT after primary survey?

- Any injury associated with SBP<70mmHg at any stage (an indication of severe haemorrhage and high likelihood of complications)
- Penetrating abdominal and chest wounds associated with haemodynamic instability or generalized abdominal tenderness or FAST+ on abdominal windows
- Any gunshot wound to the abdomen
- Blunt or penetrating chest injury with initial output >1.5L or >200mL/hr
- Penetrating neck wound with airway compromise or arterial extravasation
- Blunt abdominal injury associated with frank hypotension unresponsive to the initial bolus of IV fluid

In these situations, operative or angiographic interventions become part of the primary survey and take precedence over other interventions or investigations

How fast should I be getting them to definitive care?
These are based on current trauma performance indicators
Laparotomy for abdominal injury – 2 hours from time of injury
Craniotomy for intracranial haemorrhage – 4 hours from time of injury
Debridement and fixation of open fractures – 6 hours from time of injury

In addition, you should aim to have arterial haemorrhage associated with pelvic fractures embolised within 2-4 hours from time of injury and thoracotomy for chest injuries performed within 2 hours of injury.

What should I be scanning?
See below (under section 'The CT scan')

OTHER IMPORTANT QUESTIONS TO ASK DURING PRIMARY SURVEY

When should the chest and pelvis X ray be taken?
All blunt trauma activations are to have a chest and pelvis X ray performed. Any patient with a penetrating injury to the torso who is able to sit up must have an erect chest X ray performed

The chest and pelvis X ray should be taken as soon as the initial primary survey is complete (i.e. within 5 minutes). The patient may be rolled off the spinal board if they are stable enough, otherwise the X rays must be performed whilst the patient is on the hard board. If the patient does not require any urgent interventions, the cervical spine series may also be taken at this point. At no stage is the CXR or pelvic X rays to wait until the completion of the secondary surveys. Any necessary limb X rays should wait until the patient is stabilised and can be performed in the radiology department. If the patient is unstable, the radiographer should be asked to return for repeat Chest X rays after intubation or chest tube insertion

When should we intubate?
Immediate mandatory intubation during the first 5 minutes of primary survey
- Arrest or apnoea
- Massive upper airway disruption due to trauma or burns
- Severe head injury (GCS<9) with evidence of pupillary asymmetry
- Inability to keep oxygen saturations above 90% despite oxygen via non rebreather mask

When can intubation wait until the rest of primary survey is completed?
- Depressed level of consciousness
- Pre emptive intubation for severe multisystem injury or burns

In an appropriately supported airway (suction, oropharyngeal airway adequate ventilation and the presence of an airway doctor) the following should ideally be checked before intubating a trauma patient.

1. Exclude Pneumothorax – intubation can convert a simple pneumothorax into a tension pneumothorax
2. Give 100% oxygen to allow for pre-oxygenation
3. Obtain intravenous access and IV fluids. Make some assessment of likely sources of bleeding – intubation and positive pressure ventilation can unmask hypovolaemia and precipitate circulatory collapse. This is especially true for blunt and penetrating chest trauma
4. Perform a brief neurological examination – documentation of initial best GCS score is important for neurosurgical assessment and prognosis.

5. *What fluid should I give and how much do I give?*

If there is evidence of haemodynamic instability in blunt trauma, 2L of crystalloid are initially given as a bolus. If the patient does not respond adequately packed cell transfusion is given through a fluid warmer. If the patient is requiring packed cells, anticipate the need for fresh frozen plasma and other clotting products after the third unit of packed cells. Once the patient requires blood transfusion in the resuscitation bay, both Trauma Surgeon on call and ED Consultant on call are notified.

Fluid therapy in potentially unstable patients and its response does not determine the eventual disposition. Nor does it improve survival in bleeding trauma patients. It is merely a temporizing measure to enable;

1. Blunt trauma patients to get to CT to identify the source of haemorrhage
2. To buy some time to get patient prepared for operating theatres

For penetrating injury with any evidence of haemodynamic instability, the aim is to get the patient as quickly to OT as possible. Take O negative blood with you on transfer to OT, but do not wait for patients to “stabilise” before transferring the patient.

When should the chest drain output be of concern?

Stable blunt chest trauma with <u>any</u> blood in the chest drain warrants a chest and abdominal CT. If there is evidence of haemodynamic instability in the presence of haemothorax, the cardiothoracic registrar must be present with the view to urgent thoracotomy.

If there is more than 1.5L of blood returns upon chest drain insertion or >200mL/hr after that, then an urgent thoracotomy is indicated. The most likely diagnoses are great vessel injury, intercostal artery bleeding or massive pulmonary haemorrhage. In these situations, the BP will invariably drop after chest tube insertion or intubation; therefore you must be prepared for urgent transfer and also the possibility of a resuscitative thoracotomy.

Have the bloods and trauma series been ordered?
Ensure a X match is sent for all patients with evidence of haemodynamic instability. Check the trauma series for abnormalities requiring further assessment or imaging. Follow up the initial INR in patients with evidence of haemodynamic instability. Coagulopathy should be treated early especially in patients who are hypotensive and hypothermic.

How do I apply a pelvic sling?
Fold a bed sheet into a 20cm wide sling, wrap around the pelvis and fold over anteriorly. Pull the opposite ends tight using a person on either side and attach clamps to the middle to secure

When is an arterial line appropriate?
An arterial line is rarely indicated in the initial management of trauma. A patient with severe head injury waiting to go to neurosurgical intensive care may require an arterial line to monitor for sudden changes in mean arterial pressure. An unstable patient being transferred to the Burns Unit at Concord is another example.

When should I do a FAST?
A FAST should be performed during the primary survey but should not delay the performance of the initial X rays (CXR and PXR). The FAST is designed to aid decision making and operative approach for blunt trauma patient in Grade 3-4 shock who are about to go direct to operating theatres. The main priority is the rapid identification of haemoperitoneum or pericardial tamponade. In the absence of a reliable FAST, the operative approach is decided by the Trauma Surgeon on call. The FAST must be performed or supervised by a suitably experienced or accredited ED doctor. The results of a FAST should not be used to “clear” the abdomen in an otherwise haemodynamically stable patient.

SECONDARY SURVEY

Conduct of Secondary Survey

When initial X rays are completed, the TTL should then instruct the surgical registrar to perform a head to toe examination. This should include at a minimum, examination of scalp, ENT, eye, cervical spine, torso, log roll, all limbs and perineum. The purposes of the secondary survey are to;

1. document superficial injuries
2. Determine the need for further imaging
3. Determine adjunctive treatment

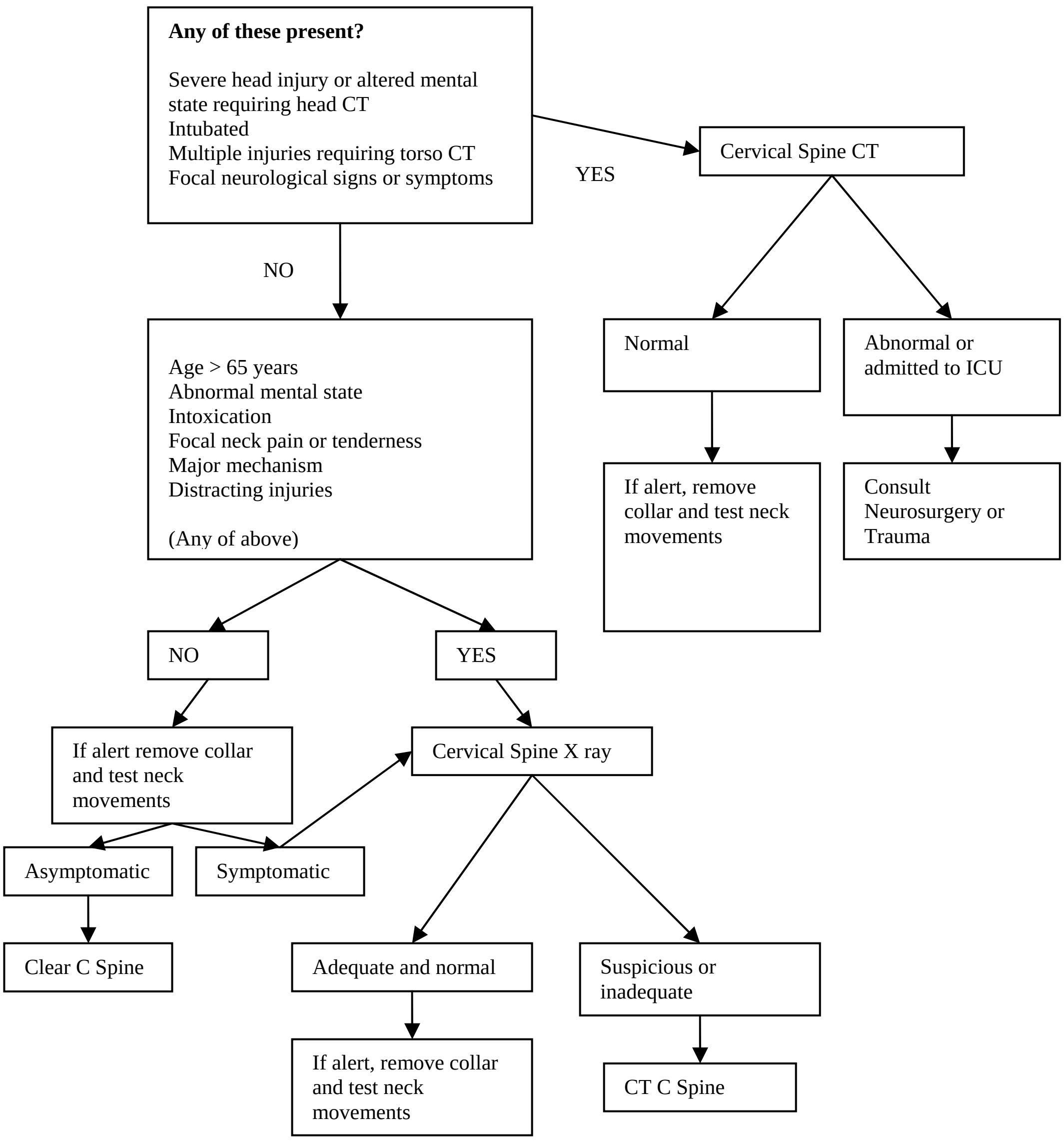
The findings should then be communicated to the TTL.

Necessary considerations at this point are

1. Analgesia
2. Limb splinting
3. ADT
4. Antibiotics for open fractures
5. Indwelling catheter and NG tubes
6. Core temperature if haemodynamically unstable
7. Check all initial X rays and blood test results, in particular INR
8. Blood alcohol
9. Notify patient and family of management plan and progress
10. Documentation and clinical handover to the general surgical registrar and ICU
11. Cervical spine clearance and further assessment if indicated

All these issues should be addressed by the 30 minute mark. Preparations should now be under way for transfer of the patient to CT scan if required. Oral contrast should be given if appropriate (patient alert, cooperative and not vomiting or has an NG in situ)

How do I assess and clear the cervical spine?



When should a blood alcohol sample be sent?

(NSW Health – policy directive as of Feb 2005)
Any person who is 15 years of age or over and presents to ED for assessment or treatment as a result of any accident and is a;

- Driver of any motor vehicle
- Occupying the drivers seat at time of accident and attempting to put the vehicle in motion after the incident
- Pedestrian
- Horse-rider
- Person with driver's license accompanying a learner (L plate) driver involved in an accident
- Operating a marine vessel

The doctor is under duty to take the blood sample regardless of consent. A registered nurse may take the sample on behalf of the doctor. In these circumstances, the sample is deemed for legal purposes to be taken by the doctor.

Exceptions to the above include situations where;

- Taking the blood sample potentially compromises care of the patient (e.g. urgently needs to go to theatres and cannot wait)
- The patients behaviour is such that the sample cannot be safely taken
- More than 12 hours has elapsed since the incident

If the blood sample cannot be taken, the reasons should be documented in the notes

When should I place a gastric tube?

- All intubated patients
- Patients with moderate to severe head injury who are at risk of deterioration after admission (e.g. those with significant intracranial haemorrhage being treated conservatively)
- Patients who are alert and cooperative but have vomited repeatedly
- Evidence of blunt or penetrating abdominal injury

Placement of gastric tubes should be confirmed by aspiration, auscultation and chest radiographs. Orogastric approach is used if there are indications of base of skull fracture. After confirmation of tube placement, stomach contents should be aspirated and the tube placed on free drainage

THE CT SCAN

What should I scan?

- **Head CT** – any trauma activation patient with altered mental state, GCS < 15 at time of assessment or evidence of major external head injury
- **C spine CT** – High risk cervical spine patients (including those going for head CT), inadequate C spine X rays. The CT Radiology Registrar needs to be notified of all CT C Spine requests.
- **Chest CT** – unexplained central chest pain, multiple rib fractures, haemothorax, abnormal supine chest X ray, patients going for head and abdominal CT
- **Abdominal/Pelvic CT** – abdominal pain or tenderness, gross haematuria, major pelvic fractures, seat belt sign, penetrating flank, groin or upper quadrant injuries, (anterior penetrating injuries most likely require surgical exploration, though this should be discussed with the Trauma Surgeon on call) and multiple orthopaedic injuries
- **Head/C Spine/Chest/Abdomen/Pelvis** – alert or intubated patients with multiple system injuries (including multiple orthopaedic injuries), intubated patients with evidence of haemodynamic instability, significant mechanism (prolonged extrication, ejection from vehicle, rollover, pedestrians with multiple injuries, confirmed fall from height > 3m with obvious multiple injuries)

Which patients should not be scanned?

Traditional teaching is that unstable patients must not go to CT scan. However, this is simplistic and does not take into account grades of instability and the fact that modern CT scans if properly anticipated and organized can be performed within minutes. In general, patients requiring urgent operative intervention should not go for CT scan. In particular patients with Grade 4 shock – that is deteriorating hypotension (SBP <70-80mmHg) due to bleeding that is unresponsive to fluid therapy, must not go for CT scanning. The window of opportunity has passed for these patients and the decision for the trauma team is what operative approach to take and how quickly this patient can get there. Patients with Grade 3 shock (hypotension responsive to recurrent fluid boluses) may go to CT scan only in consultation with the Trauma Surgeon on call and with full supportive measures and monitoring available. Such patients are assumed to have significant bleeding and the role of the CT is to identify where the bleeding is coming from. The Radiographers must be ready to perform the CT as soon as the patient arrives in the Radiology Department. This means they are notified as soon as the primary survey is complete.

What should I bring to CT?

The decision to take a patient with evidence of haemodynamic instability should be made in consultation with the Trauma Surgeon on call or ED consultant. If there is any evidence of haemodynamic instability, ensure the following are present;

- Anaesthetics or ICU registrar
- Surgical Registrar
- Senior capable nurse
- Airway equipment and Bag valve mask
- Oxygen tank
- Monitoring devices
- IV access patent x 2 secured and IV lines functioning with full IV bags
- O negative or X matched blood if available - 2 units
- Documentation

How can I expedite CT scanning?
If you know a major trauma is coming and you have time, it is worth notifying the CT radiographer and Registrar prior to arrival. This opens lines of communication and means that there are less likely to be delays. The most important person in this equation is usually the radiographer so it is worth talking to them directly.

Otherwise ensure that the Radiology Registrar is contacted at the completion of the Primary survey. This should occur by the 15 minute mark at the latest and gives them a good half hour to complete existing scans, come to hospital or set up the machine. Any CT imaging should be commenced at the 1 hour mark at the latest. <u>It is inappropriate for trauma patients to wait until morning for CT scans. This only delays diagnosis and definitive management and is associated with increased morbidity and mortality.</u>

Why am I doing the scan in the middle of the night?
- *Head CT* – intracranial haemorrhage requiring neurosurgical consultation
- *C Spine CT* – Allow clearance of C spine for alert and intubated patients in ICU
- *Chest CT* – a normal CXR does not exclude blunt aortic injury. Significant force to the mediastinum should be suspected with the mechanism of injury (almost always driver or front seat passenger with significant deformation, unexplained chest pain or pedestrian with multiple injuries) or seat belt bruising to the chest.
- *Abdominal CT* – Solid organ injury, clarification of source of haemorrhage in haemodynamically unstable patients – isolated pelvic haemorrhage = interventional angiogram, abdominal injury with free fluid = laparotomy.

Should I give oral contrast for an abdominal CT?
Oral contrast is not an absolute priority in CT trauma protocols. The presence of oral contrast enables the radiologist to better define bowel pathology. The main objective of an abdominal CT is to identify

1. Haemoperitoneum
2. Active intravenous contrast extravasation
3. Solid organ injury

Hollow viscus injury due to blunt trauma is rare and difficult to diagnose on CT even at the best of times. Therefore, if the patient needs to go to scanner urgently, oral contrast should not delay this. If the patient has an NG tube confirmed in the stomach, then it is appropriate to give oral contrast if there is sufficient time. If the patient is alert and cooperative and is able to drink through a straw while in a hard collar, then time permitting, oral contrast can be given. The default option for diagnosis of blunt bowel injury remains admission for serial examination and or laparoscopy.

CLINICAL HANDOVER

Documentation
Documentation is part of the communication role of the TTL. The documentation on the trauma assessment form constitutes the medical record and should therefore reflect all your findings, discussions and management plans. The trauma assessment form is designed to be intuitive as possible but this does not preclude legible and contemporaneous notes. In addition all trauma team members present at the trauma should write their names on the trauma sheet.

When should I be documenting?
Documentation should occur during prehospital handover and during the secondary survey. If the patient needs to go to OT urgently, documentation can be delayed until the completion of patient transfer.

Who should I handover the patient to?
If the patient requires admission under Trauma, the patient should be handed over to the General Surgical Registrar. This should occur ideally when reviewing all the imaging results and blood results. The patient gets admitted under the Trauma Surgeon of the day for 24 hours regardless of the nature of injuries. If the Surgical Registrar is not present, then they should be paged and contacted about the patient. This discussion should be reflected in the notes.

3. NOTES FOR POTENTIALLY DIFFICULT SCENARIOS

Difficult airway

Have an algorithm for difficult airway in trauma. This includes the use of gum elastic bougie and BURP manouvers. If endotracheal tube cannot be placed after 2 attempts by the Anaesthetics Registrar or yourself, then the both the Anesthetics Consultant and the Trauma Surgeon on call need to be called in. If the patient cannot be ventilated after failed intubation attempts, then a surgical airway needs to be established. Surgical cricothyroidotomy is the preferred method. If the patient can be ventilated, options include use of LMA as a temporizing measure, fibreoptic laryngoscopy or OT for formal tracheotomy. These decisions are made in consultation with the Trauma Surgeon on call.

Severe head injury (GCS<9)

Aims are definitive airway, CT within the hour and craniotomy within 4 hours. The neurosurgical registrar should be notified as soon as severe head injury is identified in the primary survey. If pupils are asymmetrical, then aim for *immediate* intubation, IV mannitol 1g/kg over 30 minutes and phenytoin 1g IV over 1 hour. NB Mannitol should not be given in the hypotensive patient. If no focal deficits, then support airway until primary survey complete then establish definitive airway prior to transfer for CT. If patient has frank hypotension, then the objective is to identify and correct the source of haemorrhage first before investigating and dealing with intracranial injury

Multi system blunt injury

Invariably need total body CT scan unless indications for immediate laparotomy Ensure CXR and pelvic X rays performed early and if stable can go around to department for limb X rays. Notify orthopaedic registrar early. Likely will need core temperature and active warming

Penetrating abdominal injury

The most important rule for the TTL is to complete the primary survey before focusing on the abdomen. This becomes important for epigastric and upper quadrant wounds which can sometimes violate the pleura causing pneumothorax or worse still penetrate the pericardium. The next consideration is that bullet trajectory in the body is impossible to predict, so that abdominal GSW should be assessed as potential chest injury until proven otherwise.

When the abdomen is being assessed during the secondary survey, the questions to ask are

1. Is there haemodynamic instability?
2. Will the physical examination be reliable and if so, is there local or generalized tenderness?
3. Is there omentum evisceration or free gas on an erect CXR?
4. Is the FAST positive?

In the presence of any of these findings, the patient should be taken to the operating theatre without delay. Another relative indication is the inability to assess the abdomen for peritonism. Patients with severe head injuries or intoxication or undergoing urgent surgery for other indications are included in this group. In the absence of any of these findings, there is time for either further evaluation with serial examination, CT or laparoscopy depending on the preferences of the Trauma Surgeon. Digital probing and local wound exploration has no role in the evaluation of penetrating torso injury.

Penetrating chest injury
Cardiothoracic registrar to be notified on BAT call
Prepare chest drain tray
Tell radiographer that all you need is an erect chest X ray
Give 100% oxygen, get IV access and erect chest X ray on arrival
Perform a quick log roll to check for other wounds
Chest drain to be inserted as soon as CXR confirms PTX or haemothorax

If wound in cardiac box and any evidence of haemodynamic instability or arrest with return of circulation, must go straight to OT after chest X ray. Depending on the urgency of transfer and availability of OT, the CXR can be chased up and the chest drain inserted while in OT. An FAST/ECHO may help clarify the operative approach for these patients.

If wound in cardiac box and patient is stable, then arrange FAST/ECHO. If not available within 15 minutes, then arrange for pericardial window in OT. This decision should be made in consultation with the Cardiothoracic Surgeon on call. If there is no obvious pericardial collection and the patient is haemodynamically stable then it is appropriate to admit to a monitored bed under trauma with view to repeating a CXR or chest CT.

If chest drain output initially 1.5L then arrange urgent thoracotomy. If there is evidence of haemodynamic instability do not wait for chest drain output. If frank hypotension, give oxygen, IV fluid bolus, chest drain if indicated and arrange urgent thoracotomy

Do not consider pericardiocentesis who is peri-arrest. The relatively small amount of blood collecting in the pericardial sac causing tamponade is often clotted and will be impossible to aspirate. The treatment of choice is resuscitative thoracotomy with release of the pericardium.

Pelvic fractures and haemodynamic instability
There is considerable debate about the correct order of investigations/interventions in patients with a major pelvic fracture. The following are a guideline only. In this situation it is worth involving the trauma surgeon, the orthopaedic surgeon and interventional radiologist *early*. Immediate availability of one resource over another may facilitate which treatment to use (e.g. middle of night, theatres ready now and radiologists off site or middle of day, radiologist available in 10 minutes and theatre >30 minutes).

If haemodynamically unstable and obvious pelvic fracture on primary survey or pelvic X ray reveals a widened pubic symphysis, then apply a pelvic sling.

Signs of significant pelvic fracture are
1. haemodynamic instability
2. perineal or scrotal ecchymoses
3. Blood at urethral meatus
4. open book, lateral compression, vertical shear on X ray

If frank hypotension unresponsive to initial fluid bolus – perform a FAST or abdominal examination (if FAST unavailable). If FAST grossly positive or solid organ injury likely based on clinical examination, then consider urgent laparotomy with external fixation or pelvic packing followed by interventional angiography.
If FAST negative and no evidence of gross abdominal injury clinically, then proceed to urgent embolisation. Contact Trauma Surgeon and ED Consultant to confirm decision for interventional angiogram and call the interventional consultant. A CT may be required to clarify the source of bleeding, however this decision should be made in consultation with the Trauma Surgeon. A CT allows precise localization of pelvic bleeding and identification of haemoperitoneum mandating urgent laparotomy. If both abdominal and pelvic active bleeding on CT, the priorities are to treat the abdominal bleeding with laparotomy first, together with external
fixation in OT if indicated and pelvic packing followed by interventional angiogram.

Spinal shock
This occurs in severe spinal injury involving the mid thoracic spine and above. The indications of this are hypotension (often around 80mmHg) with relative bradycardia unresponsive to fluid boluses. The picture can be similar to grade 3-4 shock. The clinical clues are, high grade mechanism of injury (fall from height normally or high speed impact, paraplegia or quadriplegia, priapism and gross deformity on log roll and midline palpation. Often, this can only be clarified by reconstruction of chest and abdominal CTs. You will need exclude abdominal, pelvic or chest injuries as a cause of hypotension before diagnosing spinal shock.

Massive facial injuries
The primary consideration is airway protection. Definitive airway must be established if bleeding or anatomic deformity is such that the airway is compromised. Massive facial bleeding caused by Le Fort fractures can be temporized by placing a nasogastric tube through the nose and out the mouth then applying gentle traction. Place a nasal catheter in the other nostril and place packing material in the mouth after intubation. The definitive treatment is fracture fixation with arterial embolisation.

Major Burns

Intubate early if respiratory distress, pharyngeal oedema, stridor, and soot in mouth, nasal hair singeing associated with burns sustained in an enclosed space or extensive facial burns

Supplemental oxygen to keep saturations above 95%

Remove all burnt clothing and cover with clean dry sheet

Parklands formula: 2-4mL/kg/%BSA affected by partial or full thickness burns Give ½ in first 8 hours and rest over next 16 hours

Measure temperature

Urinary catheter – aim for urine output 0.5ml/kg/hr

Ensure adequate analgesia

Ensure tetanus up to date

Arrange transfer early to a Burns Unit if there are no other major injuries

The Lethal Triad (does not refer to Kong, Cliff and I)

Hypothermia, coagulopathy and acidosis are common in multisystem traumas with hypotension. This is due to loss of clotting factor, haemodilution, release of inflammatory mediators and hypoperfusion. The lethal triad must be prevented in all haemodynamically unstable trauma patients as this accentuates bleeding and makes haemorrhage control during surgery very difficult.

Hypothermia (temperature less than 35.5 in a trauma patient) – Treat with Bair hugger, fluid warmer and warming blankets. Use rectal temperature probe.

Avoid over transfusion – aim for SBP of 90mmHg. Increasing the number of blood products does not change mortality. Only the time to definitive care makes a difference

Coagulopathy – early FFP, activated factor 7 after 8 units of packed cells

Acidosis – ensure adequate perfusion. Maintain a systolic BP of 90mmHg

4. OVERVIEW OF TRAUMA DRILL IN THE FIRST HOUR

BAT CALL

PREPARATION

- Activate trauma page
- Inform triage and nursing team leader
- Clear resuscitation bay
- Check equipment – airway trolley, chest drain set, IV trolley, fluid warmer, FAST machine turned on
- Protective gear – blue gown, goggles and gloves on all team members
- Lead gowns on TTL and anaesthetics registrar
- Team members introduced and briefed
- Ensure any necessary early notifications – Trauma surgeon on call, ED consultant, Blood bank, Radiology

AMBULANCE HANDOVER (time zero)

- If stable, to conduct handover first with other ambulance officer undoing buckles on stretcher. Team to stand back and listen to handover and TTL to start documenting at the end of the bed
- If unstable, immediate transfer onto bed with formal handover after primary survey
- Ambulance officers to remain until at least the completion of primary survey

PRIMARY SURVEY (1 minute mark)

- **Airway** – relieve airway obstruction
- **Breathing** – Start oxygen, auscultate and commence high flow oxygen
- **Circulation** – Measure BP, pulse Obtain IV access and bloods, commence IV fluids if haemodynamic instability
- **Log roll patient off spine board** if patient condition allows, obtain chest and pelvis X rays and get C spine series if indicated as well
- **Delegate** someone to order the bloods and trauma series
- If patient likely requires intubation or chest drain then inform the radiographer that likely needs repeat X rays

ASK FOR PRIMARY SURVEY SUMMARY
Definitive measures (3-10 minutes mark)

- **Airway** – intubation
- **Breathing** – CXR, chest drain, arrange urgent thoracotomy
- **Circulation** – Pelvic X ray, pelvic slings, compression, wound stapling, FAST, arrange urgent OT. FAST to be performed during or after X rays

ASK FOR PRIMARY SURVEY PROGRESS AND OUTLINE MANAGEMENT PLAN TO THE TEAM

ASK THE IMPORTANT QUESTIONS AND START MAKING TELEPHONE CALLS (10-15 minute mark)

- *Is the patient haemodynamically unstable?*
- *Who do I call for help?*
- *Should this patient go directly to OT?*
- *What should I scan?*

TRANSFER TO URGENT DEFINITIVE CARE (15 minutes mark)

- Transfer to operating theatres, interventional angiography if urgently required needs to be arranged at this point

SECONDARY SURVEY (15 minute mark)

- Performed by the surgical registrar
- Discussion and documentation of findings
- Arrangements for further imaging
- Start documenting in Trauma Assessment Form

ASK FOR SECONDARY SURVEY SUMMARY AND HANDOVER PATIENT TO SURGICAL REGISTRAR IF REQUIRING TRAUMA ADMISSION

ADJUNCTS

- Analgesia
- Limb splinting
- Limb X rays
- ADT
- Antibiotics for open fractures
- Indwelling catheter and NG tubes
- Core temperature if haemodynamically unstable
- Check all initial X rays and blood test results, in particular INR – coagulopathy should be identified early and corrected
- Ensure blood alcohol is sent and note serial number in notes
- Notify patient and family of management plan and progress
- Documentation and clinical handover to the general surgical registrar and ICU

TRANSFER TO CT SCAN (45 minutes mark)
Ensure the following are present if any evidence of haemodynamic instability

- Anaesthetics or ICU registrar
- Senior Registered Nurse
- Airway equipment
- Oxygen tank
- Monitoring devices and pulse oximetry
- IV access patent
- negative or X matched blood if available
- Documentation

CLINICAL HANDOVER (60 minute mark)

- Documentation of all findings, discussions
- Check results of all imaging and initial blood tests
- Handover to surgical and intensive care registrar
- Ensure all relevant people notified of changes

OVERVIEW OF TRAUMA DRILL FOR PATIENTS IN GRADE III –IV SHOCK

Patients in this category include

1. Blunt trauma with multiple torso and limb injuries with frank hypotension SBP <70mmHg and or pre arrest
2. Penetrating torso injury with frank hypotension or pre arrest

- **Protective gowns**, gloves, goggles and lead gown
- **Notify Trauma Surgeon on call**, Operating Theatres and Blood Bank
- Penetrating Chest wounds – contact Cardiothoracics Registrar
- **Identify Team roles**
- Brief your team about what the plan will be (aim for immediate IV access, X match, O negative blood, X rays performed with bloods and FAST scan)
- On arrival, **immediate transfer** to the trauma trolley (*zero minutes*)
- **Assess and clear ABC** – Clear and protect airway, identify tension and obtain IV access, measure BP and place monitoring leads and start blood transfusion with O negative blood if required
- **Maintain SBP 85-90mmHg**
- Ensure X match for 10 units of blood and 4 units FFP sent and Blood Bank contacted
- ***Perform Chest X ray (and pelvic X ray if blunt trauma) (5 minute mark)***
- **Perform FAST during X rays**
- Establish and confirm definitive airway
- If significant chest deformity, pneumothorax or penetrating wound, Surgical Registrar/ICU registrar to insert chest tubes (bilateral if required) and call Cardiothoracic Registrar
- While X rays are being performed decide where the bleeding is most likely to arise from;
- *Chest* – haemothorax, penetrating wound in cardiac box, widened mediastinum
- *Abdomen* – penetrating wound, distension or bruising, FAST positive
- *Pelvis* – gross instability, perineal haematoma
- Contact Trauma Surgeon on call with this information
- Inform entire team and patient of management plan (*10 minute mark*)

- **Decide whether transfer to Operating theatres, CT or Angiography**
- Contact Neurosurgical Registrar if severe head injury or vertebral fracture
- Review the X ray results and decide if patient needs further chest tubes or pelvic slinging

- After secondary survey, **warm patient** with Bair Hugger, space blankets and fluid warmer. Get core temperature and IDC (if time available)
- **Establish monitoring, oxygen and other equipment necessary to transfer this patient urgently to definitive care. (*15minute mark*)**
- **Check INR** and handover all clinical details to the Surgical Registrar, ICU Registrar and Anaesthetics Registrar

5. COMMON PITFALLS

Not calling a trauma – an injured patient who meets criteria must get a trauma page whether this was identified at triage or by assessment in the emergency department. This mobilizes the appropriate resources to the patient and allows treatment to be expedited.

Getting involved in procedures - this makes it difficult for all but the most experienced consultant to maintain control over the key priorities and lines of communication. Avoid this temptation. Unfortunately, this comes often when the patient is most unstable and in need of urgent definitive care. Your role in the trauma is to notify and mobilize.

Not believing the vital signs – trying to explain away tachycardia or hypotension is a common pitfall and will often delay diagnoses and definitive management. The cause of any haemodynamic instability in trauma is ongoing haemorrhage until proven otherwise. Avoid calling a patient stable if there is evidence of bleeding requiring ongoing fluid boluses.

Not informing consultants early – the Trauma Surgeon and Emergency Consultant on call after hours are there to make the difficult decisions in trauma. Your role is to know when to call them for advice. This will expedite definitive care and prioritise any further investigations

Waiting for CT scans – this can be avoided by calling the CT registrar on call early in the trauma. It should be clear to you by the 15 minute mark what scans the patient will require. It may not be initially clear whether the patient will need a C spine CT. In these circumstances be sure to check the C spine series first before sending the patient over to CT. The diagnoses must be made at the time of initial trauma assessment. Any decision not to do so must be discussed with the trauma surgeon on call.

Hypothermia
Make sure all patients with evidence of haemodynamic instability have a core temperature measured and if this is less than 36 degrees, start active warming measures with a Bair Hugger and space blankets. Hypothermia (temperature less than 35 degrees) is independently associated with poor outcomes in patients with haemorrhagic shock.

Disagreements within the trauma team
Conflicts during trauma can be minimized by ensuring communication and establishing both the roles and the management goals of the trauma team.

Common problems are surgical, anaesthetics or intensive care registrars taking over and calling the shots, arterial lines, waiting for IV fluid or blood products, disagreements about the need for imaging and notifying consultants of unstable situations. This can all be avoided with clear communication and an understanding of basic trauma protocols. Remember in difficult situations, it is better to notify Consultants earlier rather than later. The Trauma Surgeon and the Emergency Consultants on call are ultimately responsible for decisions made regarding trauma patients. Any other issues relating to conduct of the trauma team needs to be referred to the Trauma Service as soon as possible.

For a hypotensive trauma patient with multiple injuries your brief to the trauma team should include the following;

"Hi, I'm … and I'm the Trauma Team Leader. Let's get the patient off the stretcher NOW. Let's get the ABC assessed and cleared, IV access in and a chest and pelvis X ray taken after a quick log roll. I want to commence O negative blood called up from blood bank and operating theatres notified. We need to determine why this patient is unstable and we need this all done within 10 minutes of arrival. We then need to call the Trauma Surgeon on call +- Radiology Registrar with the Primary Survey summary"

This establishes the three most important teamwork priorities for any unstable trauma patient;

- Who's in charge and the need to work as a team
- The game plan, including the need to notify Consultants early.
- The sense of urgency

To the team, "*Can I have a summary of the primary survey findings please?"*

To the nursing team leader, *"I need a running tally of IV fluid input and the following things done (Analgesia, ADT, IDC antibiotics, fluid warmer….) Could you arrange a core temperature and set this patient up for urgent transfer to …."*

To the radiographer: "*Can you have the X rays ready ASAP and phone the resus bay when they are?"*

To the team, *"I (or Surgical Registrar) have called Dr So and So, who says we should go to the CT scanner/angiography/operating theatres. Can we get 4 units of packed cells (O negative if required), FFP, monitoring, oxygen, Bair Hugger and space blanket ready. The CT people will be ready in 10 minutes, so let's be ready by then.*

The ability to lead the team in such a manner and ensure tasks are performed in the first 10 minutes underscores the importance of having a clear game plan in your mind and the confidence to know when to call for help.

Waiting for blood products

There are problems with ordering blood products once patient identity and MRN has been formalized. If clerking patient identity results in an MRN different from the original resuscitation MRN, a new specimen needs to be sent according to blood bank policy.

As a rule of thumb, if the patient urgently requires blood, this should be obvious within the first 15 minutes of a trauma, well before the X match is processed and ready. In these circumstances, notify the blood bank and arrange for O negative or type specific blood to be available and give these while the new MRN is being processed. Remember to use the same resuscitation MRN stickers especially if there are multiple traumas. Once the patient is in theatres or in ICU, a repeat sample can be arranged on the new MRN.

"There's no team leadership" – this is a criticism often heard at feedback. It is not always a criticism of your management of trauma, rather the way the team interacts to get the job done. Part of this relates to different personalities and expectations amongst nursing staff and other doctors, the rest often relates to your own confidence and experience. Another consideration is that severe traumas are stressful, highly emotive experiences often with less than expected outcomes. This results in undue criticism. A major role of the Trauma department is to use suggestions, feedback as well as evidence to try and formulate better ways of managing trauma and ensure quality is maintained. A few points to remember;

- **Learn the trauma drill** – having a template to manage *all* traumas makes it easier to manage *severe* traumas. The drill is designed to take the uncertainty out of the initial trauma assessment and allow you to grow in confidence. The lessons in this manual have been borne out through many years experience.

- **Become experts in the trauma primary survey** – again, learn the drill, read the textbooks and discuss issues at meetings. This is the path to true leadership.

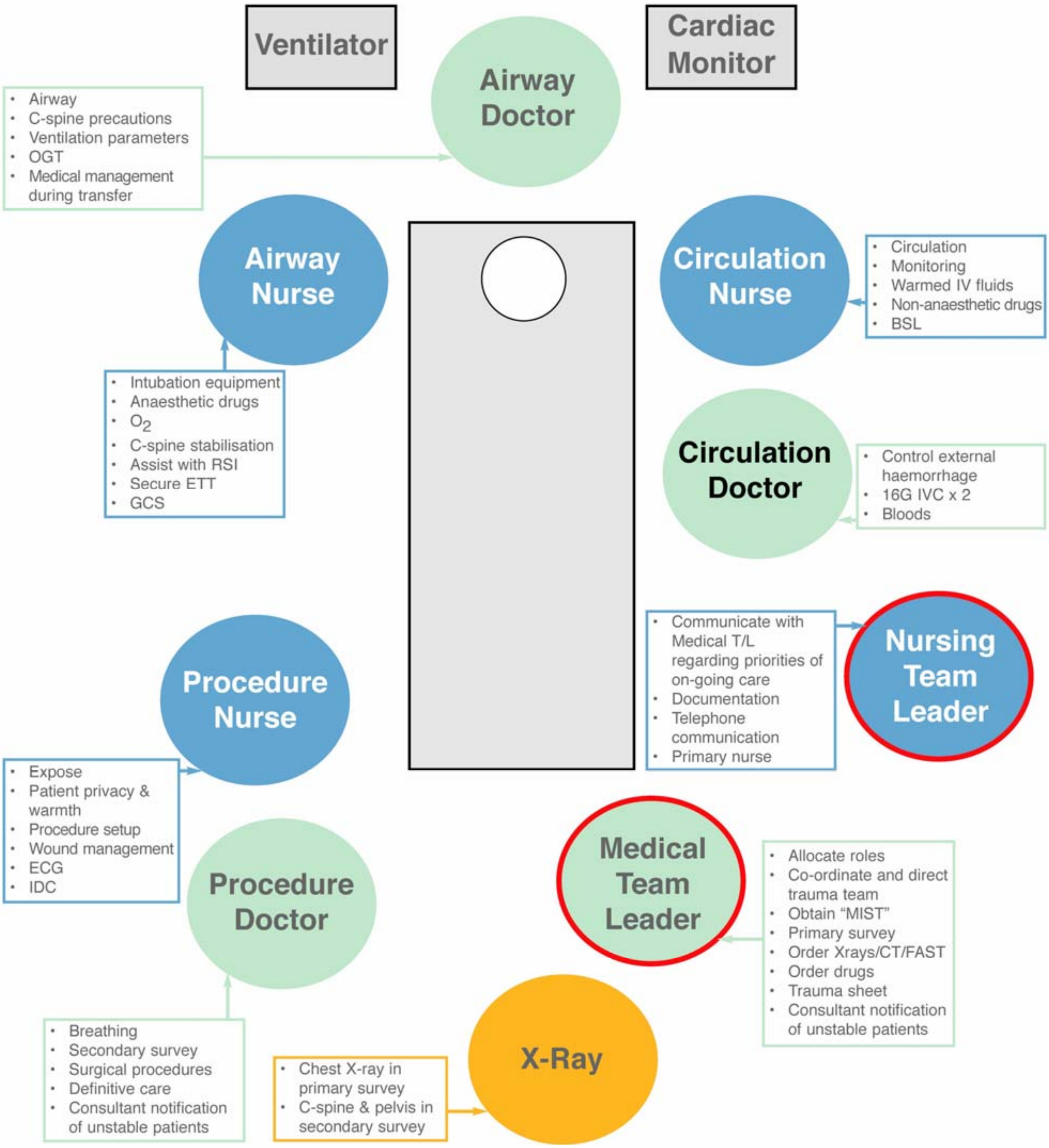
- **Communicate with your team** – This helps establish who is in control. This does not mean that you ignore the suggestions of your trauma team. It means that all findings and management decisions are directed through you and that all the roles and tasks within the trauma drill are being performed. It also means that you remain acutely aware of when to notify consultants. The consultants on call are ultimately responsible for the patients.

- **Appreciate the impact that trauma has on society** – trauma remains by far the number one cause of death and disability in patients under the age of 45 years. Some of the most critically ill patients you will ever manage in your training will be trauma patients. So as team leader in a major trauma centre, your role is perhaps the most important in the whole trauma system.

- **6. CONCLUSION**

I hope you have found the suggestions above helpful. Remember that traumas are often stressful and difficult. A good trauma team always makes it look easy. Even though the entire trauma drill may not apply to many patients, you should get into the habit of practicing it at least in your mind every time there is a trauma activation. There are also plenty of opportunities to practice the drill during trauma simulation and disaster training exercises. The Department of Trauma Services is here to help you develop your skills in trauma management and your ongoing feedback is valuable.

RPAH Trauma Floor Plan



Please remain behind the RED LINE unless asked to participate

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Roles & responsibilities approved by Royal Prince Alfred Hopital Trauma Committee August 2005

ROYAL PRINCE ALFRED HOSPITAL

TRAUMA ASSESSMENT FORM

Ward/Unit	
MRN	
Surname	
Other name	
DOB/Sex	

Date:	**Time of arrival:**	**Time of Departure:**

TRAUMA ACTIVATION CRITERIA

VITAL SIGNS	INJURY	MECHANISM
☐ SBP<90mmHg	☐ Airway compromise	☐ MVA >60km/hr
☐ RR<10 or >29	☐ Penetrating injury	☐ Ejection/rollover/occupant death
☐ GCS<14 or fitting	☐ Suspected spinal cord injury	☐ Pedestrian struck
☐ HR<50 or >130	☐ Traumatic amputation	☐ Motorcyclist with separation
	☐ Fracture ≥ 2 long bones	☐ Bicycle impact >20km/hr
☐ Age >65 SBP<100mmHg or GCS 14 or less	☐ Injury ≥ 2 body region	☐ Prolonged extrication
	☐ Severe maxillofacial injury	☐ Fall > 3m
	☐ Flail chest	☐ Transfer patient
	☐ Burns >20%BSA	

FULL TRAUMA TEAM CALL ☐		TRAUMA REGISTAR/TEAM CALL ☐		TRAUMA SURGEON /TEAM CALL ☐	
☐ Emergency	☐ General Surgery	☐ Anaesthetics	☐ Intensive Care	☐ Nursing Staff	☐ Radiographer

PREHOSPITAL DETAILS OF TRAUMA

MIST

Time of incident:	*Scene location* ☐ Direct	☐ Transfer trauma (referring hospital):		
Mechanism of injury:				
***Vitals at scene or en route*:**	BP:	Pulse:	Resp rate:	GCS:
***Interventions** prior to arrival*	Hard collar ☐	Intubated ☐	IV access ☐	IV fluid by ambulance (ml)
Medications given by ambulance staff				

PRIMARY SURVEY AND INTERVENTIONS

Airway

Patency	Patent and protected ☐		Evidence of obstruction ☐	
Airway protection	Alert ☐	Responds to voice ☐	Responds to pain ☐	Unresponsive ☐
Airway Devices	Oropharyngeal airway ☐	Endotracheal intubation ☐	Cricothyrodotomy ☐	

Breathing

Respiratory rate:		**Oxygen saturations:** %			
Chest wall	Normal ☐	Deformity ☐	Flail ☐	Contusion ☐	Penetrating wound ☐
Oxygen delivery	Nasal prong ☐	Hudson ☐	NRB ☐	BVM ☐	Ventilator ☐
Chest auscultation	Air entry equal ☐	Air entry decreased on right ☐	Air entry decreased on left ☐		
Chest drain inserted	Right ☐	Left ☐	Drain output: ml		
Chest X ray	Normal ☐	Abnormal ☐			

BINDING MARGIN - DO NOT WRITE

TRAUMA ASSESSMENT FORM

Circulation

BP: / mmHg		**Pulse:** bpm		Cap refill: seconds	
Intravenous access:	Peripheral:	Central:		Other:	
Intravenous fluid in ED	Crystalloid: ml	Packed Cells: units		FFP: units	
FAST ☐	Negative	Positive	Indeterminate	Operator :	Supervising Dr:
Pelvis X ray ☐	No fracture ☐	Fracture ☐		Pelvic stabilization: ☐	

☐ Normal	Haemorrhage unlikely, no IV bolus required	No blood loss
☐ Class 1	Minimal haemorrhage, normal vitals, IV bolus unlikely	<750 mL
☐ Class 2	Tachycardia >100 but normotensive SBP>90mmHg, IV bolus required with good response	750-1500 mL
☐ Class 3 -	SBP<90mmHg and requiring recurrent IV bolus, needs blood, surgical intervention likely	1500-2000 mL
☐ Class 4 -	SBP < 90mmHg and unresponsive to IV bolus, immediate surgical intervention required	>2000 mL
☐ Moribund	SBP <60mmHg and falling despite intervention, prepare for ED thoracotomy if appropriate	>2500 mL

Disability

Eyes *(circle)*	Open spontaneous	4	***Voice*** *(circle)*	Orientated	5	***Motor*** *(circle)*	Obeys commands	6
	Opens to voice	3		Disorientated	4		Localizes to pain	5
	Opens to pain	2		Inappropriate	3		Withdraws to pain	4
	None	1		Incomprehensible	2		Abnormal flexion	3
				None	1		Abnormal extension	2
							None	1

Total GCS score:	Pupils equal and reactive ☐ Size mm		Pupils unequal ☐ Size R L
LOC at scene ☐	Vomiting ≥2 times ☐	Amnesia>30mins ☐	Seizure ☐
Patient sedate/intubated ☐	Agents used by trauma team:		

SECONDARY SURVEY

Mechanism and Background

MVA ☐	Driver ☐	Passenger front ☐	Passenger rear ☐		
Frontal ☐	Rear end ☐	T Bone ☐	Ejection ☐	Rollover ☐	Death ☐
MBA ☐	Driver ☐	Passenger ☐	Separation from bike ☐		
Protective device	Seat belt ☐	Airbag front ☐	Airbag side ☐	Helmet ☐	
Pedestrian vs car ☐	Pedestrian vs motorbike ☐	Pedestrian vs truck/bus ☐	Pedestrian vs train ☐		
Speed in relation to trauma (include pedestrian traumas): km/hr					
Assault	Blunt ☐	Penetrating injury: ☐	Stab wound ☐	GSW ☐	Impalement ☐
Blast:	Fall ☐: fall from height metres: Home ☐ Work ☐				
Medical history:					
Medications:	Patient on warfarin/clopidogrel/aspirin ☐				
Allergies:					
Last meal:	**Tetanus** up to date ☐	Tetanus not up to date ☐	Tetanus unknown ☐		

C Spine

☐ Neurological signs or symptoms		☐ Age >65	
☐ Altered mental state/intubated		☐ Ejection, rollover	
☐ Severe head injury		☐ Neck pain or tenderness	
☐ Fall>3m		☐ Limitation to active ROM	
☐ Pelvic#, major limb#, other distracting injury			
Imaging Required ☐	☐ C Spine Series	☐ CT C Spine	None of above features, clear clinically ☐
C-Spine cleared by: Dr		Time:	

Adjuncts

☐ Urinary catheter	☐ Urinalysis results
☐ Gastric tube	☐ Antibiotics given
☐ Fluid warmer	☐ Analgesia given
☐ ADT	☐ Blood Alcohol #
	☐ Limb splinting

TRAUMA ASSESSMENT FORM

INJURIES FOUND ON PRIMARY AND SECONDARY SURVEY

HEAD/NECK	
CHEST	
ABDOMEN/BACK	
PELVIS/PERINEUM	
LIMBS	

INJURIES FOUND ON DIAGNOSTIC IMAGING (tick which tests have been done)

☐ C Spine series	(describe findings here)
☐ CXR	
☐ Pelvis X ray	
☐ Limb X rays	
☐ CT Head	
☐ CT C spine	
☐ CT Chest/Abdo/Pelvis	
☐ Other	

MANAGEMENT PLAN

PROCEDURE/TREATMENT	TIME PERFORMED	DESCRIPTION OF PROCEDURE
1.		
2.		
3.		

Hb:	Ptl:	Creat:	Urea:	Base excess:	INR:

DISPOSITION AND CONSULTATIONS

AMO:	Time contacted:	Patient/Family notified:	
CONSULTATIONS & TIME OF NOTIFICATION	☐ **Orthopaedics** ☐ **Plastics**	**NAME OF DOCTOR CONTACTED:**	
	☐ **Neurosurgery** ☐ **ENT**		
	☐ **Cardiothoracic** ☐ **Other**	**TIME OF CONTACT:**	

Disposition	☐ OPERATING THEATRE	☐ HDU	☐ WARD : (*specify*)	
	☐ GICU	☐ NICU	☐ OBSERVE ED	☐ DEATH IN ED

Name / Signed:		Date/Time:

TERTIARY SURVEY
HISTORY/MECHANISM OF INJURY

INJURIES	AIS
1	
2	
3	
4	
5	
6	
7	

CLINICAL ASSESSMENT				
Vital signs	Pulse bpm	Blood pressure mmHg	Resp Rate /minute	
	Temperature degrees Celcius	Urine output mL/hr	O2 saturations %	Oxygen
	Glasgow coma score	Pupillary response		
Neuro				
Head & neck				
Chest				
Abdo				
Pelvis				
Back				
Limbs				

MANAGEMENT PLAN		
CONSULTATIONS		PERSON(s) NOTIFIED:
TRANSFER CARE TO		TIME NOTIFIED:

Name / Signed:		SRMO	REG	SS/VMO	**Date and Time:**

Emergency Consultant notification of unstable trauma patients

The on-call emergency staff specialist must be notified by the emergency registrar of all trauma patients who meet the following criteria:

- Systolic blood pressure <90mmHg
- Administration of blood products
- When consensus relating to treatment/definitive care is not able to be met within the trauma team

Jeffrey Petchell FRACS
Director of Trauma Services

Tim Green FACEM
Director Emergency Medicine

Surgical Consultant notification of unstable trauma patients

The on-call trauma/surgical consultant must be notified by the surgical registrar of all trauma patients who meet the following criteria:

- Systolic blood pressure <90mmHg
- Administration of blood products
- When consensus relating to treatment/definitive care is not able to be met within the trauma team

Jeffrey Petchell FRACS
Director of Trauma Services

Chris Byrne FRACS
Director of Trauma Services

PRIORITIES IN THE HAEMODYNAMICALLY UNSTABLE TRAUMA PATIENT

DEFINITIONS

- SBP <90mmHg or <100mmHg if age over 65 confirmed in the resuscitation bay at any stage
- Requiring >2L of IV fluid or any blood products to maintain blood pressure at any point during resuscitation
- Persistent tachycardia despite initial IV bolus >130 beats per minute associated with confirmed blood loss

PRIORITIES

1. Notify Trauma Surgeon on call and Operating theatres
2. Protect airway
3. High flow oxygen via non rebreather mask
4. Exclude tension pneumothorax
5. Large bore intravenous access at least 16G at two sites
6. Blood products called for and urgent X match sent
7. Source of bleeding is identified and corrected
8. Grossly unstable pelvic fractures are reduced with a long sheet sling
9. Hypothermia and coagulopathy are prevented

The decision to proceed urgently to laparotomy, thoracotomy or interventional radiology must be made within 30 minutes of arrival. In certain circumstances (e.g. multiple severe injuries) a CT may be required to clarify and prioritise the source of haemorrhage. This decision should be made in full consultation with the Trauma Surgeon on call. Transfer to Radiology or Operating theatres to identify and control haemorrhage must not be delayed in the desire to normalize vital signs, acidosis or coagulopathy.

THE END POINT OF RESUSCITATION IN THE HYPOTENSIVE TRAUMA PATIENT IS THE IDENTIFICATION AND CORRECTION OF THE SOURCE OF BLEEDING. DO NOT WAIT FOR OR RELY ON FLUID RESUSCITATION TO STABILISE THE PATIENT.

The following sites of haemorrhage must be identified and corrected urgently in the haemodynamically unstable trauma patient

1. External haemorrhage – scalp wounds with arterial bleeding, displaced or open fractures
2. Chest haemorrhage – cardiac tamponade on FAST, haemothorax >1L or >200mL/hr output through chest drain, blunt aortic injury on chest CT
3. Abdominal haemorrhage – haemoperitoneum on FAST or clinical examination, large retroperitoneal haemorrhage or active extravasation seen on CT
4. Pelvic haemorrhage – unstable pelvic fractures on pelvic X ray or large pelvic haematoma or active extravasation seen on CT

ANY SOURCE OF ACTIVE BLEEDING IDENTIFIED IN THE HAEMODYNAMICALLY UNSTABLE TRAUMA PATIENT WARRANTS IMMEDIATE SURGICAL INTERVENTION OR INTERVENTIONAL RADIOLOGY.

COAGULOPATHY IN BLEEDING TRAUMA PATIENTS

Coagulopathy in trauma patients is multifactorial but is largely due to ongoing bleeding and dilution from intravenous fluids and blood products. Coagulopathy should be treated early with Fresh Frozen Plasma and the need anticipated after the 3^{rd} unit of packed cell transfusion. The definitive treatment of trauma associated coagulopathy however remains the control of haemorrhage.

HYPOTHERMIA IN TRAUMA PATIENTS

Hypothermia impairs clotting function and is associated with increased mortality. This may be prevented by the use of warmed intravenous fluids and warmed blankets when examination is complete.

ROYAL PRINCE ALFRED HOSPITAL

TRAUMA CODE CRIMSON PROTOCOL

AIM: Arrival of trauma patients in operating theatre **within 20 minutes** of identifying life-threatening haemorrhage**.**

CRITERIA: Acute life-threatening haemorrhage needing immediate surgery.

Note: the Trauma Team will already have been activated. Code Crimson cannot be activated until the patient has arrived in ED.

ACTIVATION:

As soon as the decision is made to operate,
Switchboard is contacted on 222 to activate Code Crimson.

RESPONSE:

Switchboard
Sends "Code Crimson" to the Trauma group-page.

Medical Trauma Team Leader
Ensures primary survey completed including:
IV access, specimen sent to blood bank, CXR/PXR reviewed.
Ensures Blood Bank has activated Massive Transfusion protocol.
Ensures all Team Members have completed the following tasks.

Surgical Registrar
Contacts Consultant Surgeon.
Contacts Operating Theatre NUM (54723).

Anaesthetics Registrar
Contacts Consultant Anaesthetist and Anaesthetic Technician.

Nursing Trauma Team Leader
Ensures immediate preparations for patient transfer including transport monitor, emergency drugs/equipment, porter (if available).

Blood Bank
Contacts Trauma Team (54705) to ascertain patient details and injuries.
Activates Massive Transfusion protocol.
Issues group-specific blood as soon as possible.

Operating Theatre NUM
Ascertains from Trauma Team (54705) patient details and likely surgery (e.g. laparotomy or thoracotomy).
Prepares theatre, staff and instruments for immediate surgery.

USEFUL NUMBERS:
Trauma Team Leader 54705, ED NUM 54710, ED Resuscitation Bay 55928,
OT NUM 54723, Anaesthetic Tech 54732, Blood Bank 58033 or 57831.

Cancellation: Only the consultant surgeon can overturn a Code Crimson activation.

RPAH EMERGENCY DEPARTMENT PROTOCOL FOR EMERGENCY USE OF O-NEGATIVE BLOOD STOCK

Blood bank is now keeping **four (4) units** of O-negative blood in the blood storage refrigerator in the Emergency Department Resuscitation Bay. Each unit has two patient identification blood transfusion sheets attached to each unit of blood.

This Blood is for ***Critical Emergency Use ONLY***. Where possible O-negative blood should be obtained from blood bank in the usual manner.

The four units are tagged with the emergency dispatch tag and sampled by the blood bank prior to dispatching

The O-negative Blood can only be used for an Emergency Patient, and ordered by senior ED registrar, Staff Specialist or the Medical Trauma Team Leader

- Blood bank staff will check the blood on a daily basis (Mon to Fri)
- On Saturday and Sunday the ED nurse will check the blood is in the fridge, and contact blood bank if it is unavailable
- The blood will be rotated on a weekly basis or as per the expiry date if it has not been used

In a critical emergency when O-negative blood is required it is the Resus Nurse Team Leader's responsibility to:

- Notify **Blood Bank on 58033** ASAP when O-negative blood is used. Blood Bank will then remind staff to send the blood specimen for cross match, ASAP. It also allows for expedient delivery of cross matched blood and the conservation of O-negative blood where possible.

- Complete the two (one pink/one white) patient identification blood Transfusion sheets that come with each unit of blood. (signed by two RN's, date, time and ordering medical officer)

- Pink copy stays with the patient notes.

- White copy is faxed to blood bank ASAP. Once faxed it is to be signed, dated and timed stating that the form has been faxed.

FAX BLOOD BANK 57612

- The white form is then placed in the blood fridge for collection by blood bank

- Blood Bank will replace O-negative blood if available as soon as they have received the faxed blood transfusion form. Blood bank will contact ED when it is ready and ED will arrange for collection.
- .

NOTE: Patients that require the Emergency O negative Blood will still require a pre-transfusion blood sample and request form for a blood group and cross match.

Warning: O-negative blood is not necessarily compatible when the patient has an antibody.

CLINICAL PATHWAY FOR BLUNT CHEST TRAUMA

Department of Trauma Services, Royal Prince Alfred Hospital

Key points

- Severe blunt chest injury includes
  - significant haemothorax
  - flail chest
  - pulmonary contusion
  - multiple or bilateral rib fractures
  - any chest injury resulting in respiratory compromise
- Signs of respiratory compromise include
  - RR>30
  - Use of accessory muscles
  - Oxygen saturations < 95% despite oxygen
  - pCO2 >45mmHg
  - Deteriorating mental state
- Patients with severe chest injury must be closely monitored for evidence of respiratory compromise in the first 24 hours, particularly high risk patients (see below)
- Analgesia is an important part of blunt chest injury management
- Consult with Cardiothoracic Surgery early during initial assessment and management especially if patient haemodynamically unstable.
- Cardiothoracic Surgery must be contacted regarding EVERY patient who requires chest drain insertion.

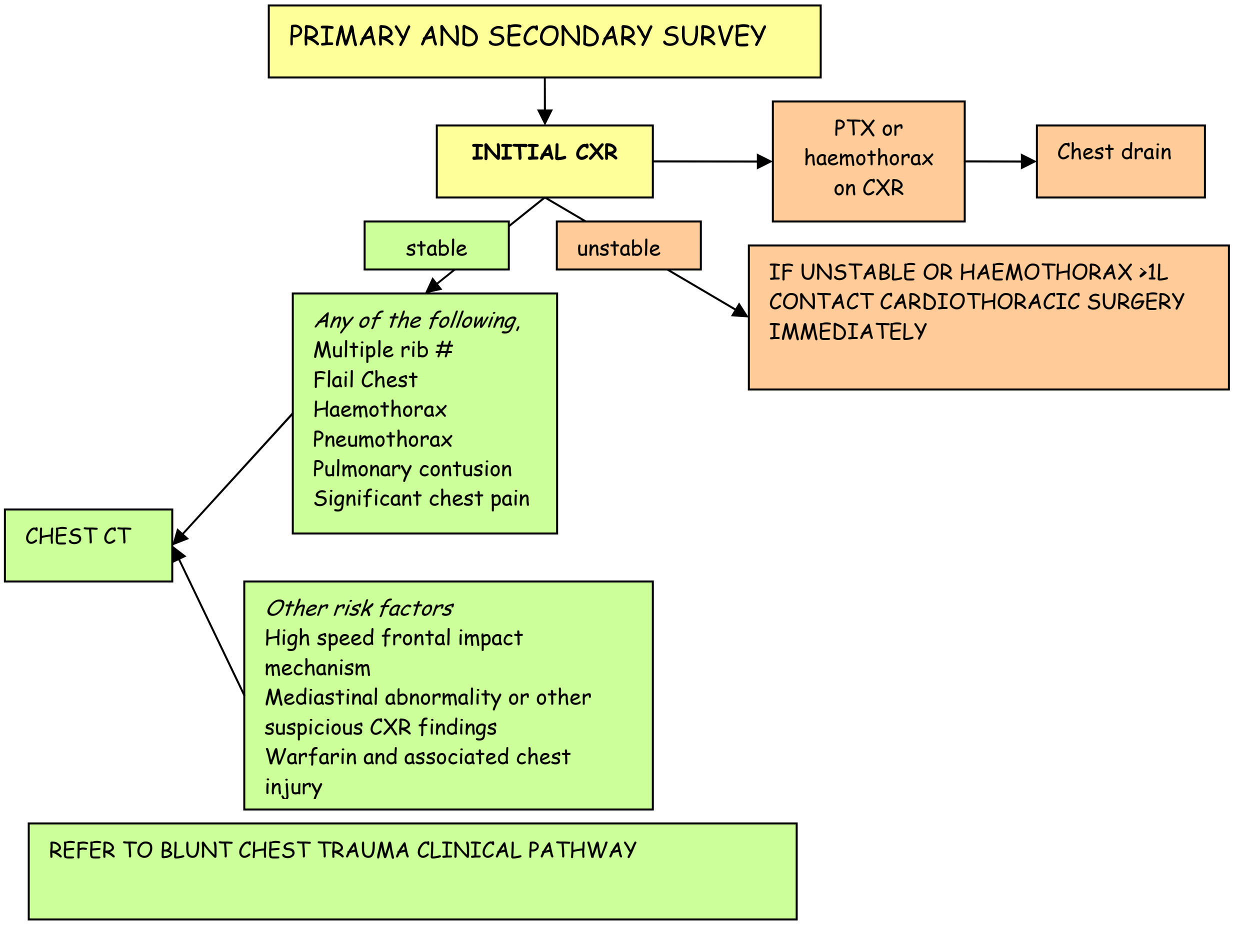
INTRODUCTION AND INITIAL ASSESSMENT

The severity of chest trauma varies from simple isolated rib fractures to life threatening injuries such as tension pneumothorax, haemothorax, aortic and great vessel lacerations and cardiac injury.

All chest injuries require a systematic approach to initial assessment and resuscitation. Patients with more severe chest injuries (significant haemothorax, multiple rib fractures, bilateral rib fractures, pulmonary contusion and flail chest) often deteriorate within the first 24 hours due to underlying lung injury, enlarging pneumothorax or haemothorax, resulting in respiratory compromise. In addition, elderly patients and those with underlying cardiorespiratory disease or other risk factors (see below) are more likely to develop late complications including pneumonia.

The following is a guide to management of severe injuries with particular emphasis to ongoing monitoring and treatment.

INITIAL ASSESSMENT OF BLUNT CHEST TRAUMA



HIGH RISK PATIENTS

Are any of the following risk factors present?

- Age >65 years old with multiple rib fractures (more than 3)
- RR >30
- Oxygen Saturations <95% on high flow oxyge
- pCO2 >45 on ABG
- Flail chest clinically evident
- Bilateral chest injury
- Comorbidities including COPD or CCF
- Patients on warfarin

→ ICU REVIEW CONSIDER MONITORED BED

CLINICAL PATHWAY FOR BLUNT CHEST TRAUMA REQUIRING ADMISSION TO RPAH

All patients with multiple rib fractures, flail segment, pulmonary contusions, pneumothorax or haemothorax due to trauma must have the following performed within 24 hours of arrival;

ADMIT

- Trauma Surgeon on call

OXYGEN

- Supplemental oxygen to keep oxygen saturation >95%

MONITORING

- Close monitoring of respiratory effort, regular RR
- Continuous pulse oximetry for high risk patients during first 24 hours
- Hourly chest drain output measurement
- Fluid balance chart
- Identify “High Risk” factors (see below)

ANALGESIA

- Regular oral paracetamol 1g qid unless contraindicated
- Breakthrough analgesia e.g. oxycodone or codeine as required
- PCA arranged if required

FLUIDS

- Maintenance fluids for 24 hours
- Avoid over resuscitation with IVF

FOLLOW UP INVESTIGATIONS

- Baseline ECG and serial ECG if ongoing chest pain
- Repeat CXR within 8 hours of admission
- Repeat FBC, EUC and coagulation profile within 8 hours of admission
- Arterial blood gas if high risk patient or deterioration (see below)
- ECHO if ECG abnormalities suspicious for myocardial contusion

CONSULTATIONS

- Trauma Surgery tertiary survey
- Cardiothoracic Surgery
- Acute Pain Service
- Chest Physiotherapy

NOTIFY

- Notify Cardiothoracic team if drain output >1L or >100mL/hr
- Notify Trauma Surgeon on call if SBP<90mmHg
- Notify ICU if deterioration or any high risk features as above
- Notify Trauma Registrar if increasing IV fluid requirements

24-48 HOURS FOLLOW UP

- Repeat CXR
- Review of chest drain
- Review analgesic requirements
- Chest Physiotherapy referral

DISPOSITION:

When the predominant injury is thoracic trauma, the following patients require transfer of care to the Cardiothoracic team after 24 hours of admission;

- Flail chest
- 3 or more rib fractures
- Any chest injury requiring a chest drain

Policy prepared by: *Department of Trauma Services*

Policy accepted by: *RPAH Trauma Committee November 2008*

For review: *July 2009*

Focused Abdominal Sonography in Trauma (FAST) Conduct and Credentialing Policy

Department of Trauma Services and Emergency Department RPAH

Introduction

FAST is a rapid Emergency Department clinical tool used to assess patients with potential thoracoabdominal injuries. Its sole purpose is the detection of free intraperitoneal or pericardial fluid in trauma patients who are haemodynamically unstable and require urgent transfer to Operating Theatres. Patients who fall into this category often have major blunt torso trauma including pelvic fractures and cannot proceed to CT scanning due to haemodynamic instability. A FAST may allow the Trauma Surgeon to predict the most appropriate sequence of operative or angiographic interventions in these critically injured patients. In many trauma centres, FAST has largely supplanted diagnostic peritoneal lavage (DPL) and has been increasingly used in conjunction with CT scanning for serial abdominal examinations.

The sensitivity and specificity of FAST in trials to date ranges from 81-98% and 94-98% respectively. Over 700mL of free intraperitoneal fluid is required for sensitivity above 90%. FAST examinations do not reliably exclude organ injury or retroperitoneal injury (sensitivity around 30%). The implications are that a positive FAST may be used to triage an unstable patient to laparotomy; however a negative FAST must not be used to "clear" the abdomen in stable patients with potential thoracoabdominal injuries based on mechanism or clinical features. CT imaging should be used in these patients. The only exception is the assessment of multiple patients involved in a disaster.

Advantages

- Rapid, reliable and repeatable
- Non invasive
- Steep learning curve

Disadvantages

- Operator dependent
- Poor sensitivity for solid organ and bowel injury
- Subcutaneous air, copious bowel gas and obesity will make interpretation difficult

This policy outlines the conduct and *credentialing* requirements for all doctors at RPAH who perform FAST examinations. This policy emphasizes the need to recognise ultrasound skills in the acute resuscitation of the trauma patient and distinguishes this process from obtaining formal *qualifications* in ultrasound.

Indications

There are clinical indications as well as indications for the purpose of credentialing.

Clinical

- Blunt or penetrating trauma patients in Grade 3-4 shock who are unable to proceed to CT scan. Such situations may include;

- Major pelvic fractures associated with blunt torso injury and Grade 3-4 shock
- Patients with major chest trauma who are in need of urgent or resuscitative thoracotomy
- Unstable penetrating upper abdomen or epigastric trauma going for laparotomy to assess pericardium prior to operation

Serial abdominal examinations on trauma patients in ED who subsequently develop abdominal signs or haemodynamic instability after CT abdomen. This will help reduce the incidence of repeat CT studies

Credentialing

- Trauma team activated patients who are stable, have potential torso injury based on mechanism or clinical findings and subsequently undergo CT abdomen or laparotomy
- Patients with intraperitoneal or pericardial fluid from causes other than trauma e.g. ascites or pericardial effusion in whom findings are confirmed in the presence of a Radiologist, Radiology Registrar or qualified Sonographer.

Contraindications

- Haemodynamically unstable patients with a clear indication for operative intervention in whom the performance of FAST would delay transfer to definitive care
- Lack of credentialed staff or experienced supervising ED Consultant

CONDUCT AND CREDENTIALING POLICY

This applies to all doctors wishing to use the ED ultrasound machine for the purpose of FAST examinations in ED. This includes Registrars in Emergency Medicine, General Surgery, Intensive Care and Anaesthetics.

Conduct

1. A doctor may perform a FAST examination if;
2. Formally qualified in ultrasound or undergoing formal qualification process (qualification or training in DDU, DMU, CCPU, FRANZR)
3. ED Consultant who has completed a recognized course in EM or trauma ultrasound. Course or workshops must satisfy current ACEM guidelines on Minimum Criteria for Ultrasound Workshops (see www.acem.org.au)
4. A doctor who has satisfied all FAST credentialing requirements at RPAH as laid out by this policy or credentialing criteria of equivalent Major Trauma Centre
5. Registrar or Specialist undergoing credentialing process who is supervised by another doctor satisfying criteria 1 or 2 (see above).

A doctor performing FAST examination must ensure that;

1. The patient is adequately prepared and the procedure explained to the patient or family
2. The examination is performed in a timely fashion and does not delay or interfere with transfer to definitive care
3. The machine is properly turned on and off and that gel media used is wiped off the patient and transducer
4. Results are documented in the Trauma Assessment Form and FAST credentialing log book (if required)
5. Only **three** consecutive FAST examinations on any one patient are allowed. This prevents excessive delays and disruption to the patient

The following windows are required for a complete FAST examination

1. Subxiphoid pericardial view
2. Hepatorenal space (Morrisons pouch)
3. Splenorenal space
4. Pelvic and paracolic gutters

Credentialing process at RPAH

Mandatory requirements

- Registrar or Consultant in a recognized specialty training program (Emergency, Intensive Care, Surgery, Anaesthetics)
- Attendance at a recognized ultrasound course or workshop whose content includes ultrasound applications in trauma. Course content should include a practical component and assessment of positive findings
- Attendance at RPAH ED teaching session relating to specific ultrasound machine used here (see Dr Jon Hayman for schedule). This will include general care of US machine, basic knobology and assessment of images. A checklist of important points will be completed and signed off on the logbook
- Completion of 20 supervised ultrasound examinations that have clinical or credentialing indications for FAST examinations. At least half of these examinations need to be performed as part of full trauma activation. 5 or more of these studies should be positive for intraperitoneal or pericardial fluid confirmed on CT, laparotomy or confirmed in the presence of a Radiologist, Radiology registrar or qualified Sonographer.
- All credentialing ultrasound studies must be documented on the FAST examination record and follow up logbook attached to the ultrasound machine

Optional

- Attendance at other ultrasound courses, workshops or meetings
- Ultrasound related chart audits or research

All documents relating to FAST credentialing are to be kept by the doctor and reviewed by the DEMT or equivalent clinical training supervisor. Once a doctor has satisfied all credentialing criteria, then he or she is said to be “credentialed for FAST examinations”. This is to be documented in the training records.

LOG BOOK

The content will includes operator and supervising doctor, patient MRN, assessment of views of the four ultrasound windows and results of CT scan or laparotomy (see Appendix). The log book will be attached to the ultrasound machine. It is the responsibility of the doctor performing FAST examination to complete log book details. Completion of the log book may occur before or after completion of recognized trauma ultrasound training course.

QUALITY ASSURANCE

The FAST credentialing log book will be reviewed on a monthly basis for documentation and accuracy. Any deviation from accepted indications will be followed up by the Department of Trauma Services. For the purposes of credentialing, an accurate FAST is one which is true positive or true negative for haemoperitoneum or haemopericardium. An inaccurate study is one which is false negative or false positive. More than a minimal amount of free fluid reported on CT is required to assess diagnostic accuracy. The timing of FAST examination and subsequent CT or laparotomy also needs to be considered.

If a FAST is deemed inaccurate, the supervising doctor may elect to repeat the study in light of CT findings and use this as a teaching opportunity. This should be documented in the log book. The images may also be stored electronically for later review. The acceptable diagnostic accuracy rate for FAST is over 90%.

POLICY REVIEW

This policy will be reviewed at 6 monthly intervals by the Emergency Department Director, Trauma Directors and RPAH Trauma Committee

APPENDIX

FAST EXAMINATION RECORD AND FOLLOW UP			
Place Patient Sticker or MRN here	*Operator* □ ED □ SURG □ ICU □ ANESTH		*Supervisor/Sonographer*
FAST indications	□ Unstable trauma	□ Stable trauma for CT	□ Ascites/Pericardial effusion
FAST details	**View**	*Adequate*	*Inadequate*
	Pericardial	□	□
	Hepato renal	□	□
	Spleno renal	□	□
	Pelvic/paracolic	□	□
FAST RESULT	□ Positive	□ Negative	□ Indeterminate
FAST FINDINGS:			
CT FINDINGS			
LAPAROTOMY FINDINGS			
RADIOLOGY/SONOGRAPHER			

GUIDELINES FOR THE ASSESSMENT AND MANAGEMENT OF HEAD INJURIES

The following is a set of recommendations for the initial assessment and management of head injured patients at RPAH. These guidelines also apply to head injured patients who are intoxicated or assaulted. In addition, patients with a Glasgow Coma Score (GCS) of 13 or less associated with trauma satisfy the current criteria for Trauma Team activation. These guidelines should always be used in conjunction with clinical judgment based on experience and expertise.

ESSENTIAL POINTS

- An accurate GCS assessment must be made at the time of triage and medical assessment
- Patients with risk factors for clinically significant brain injury should have an urgent head CT ordered
- Patients with any injury and a GCS of 13 or less (GCS 14 or less if age>65years) require Trauma Team Activation
- A patient with a head injury and GCS<9 requires immediate intubation, Neurosurgical consultation and a head CT scan within 1 hour of ED arrival
- In haemodynamically unstable patients, haemorrhage control takes precedence over neurosurgical management

DEFINITIONS

Minimal head injury – head injury with no loss of consciousness, amnesia, confusion or neurological deficit associated with a GCS of 15 on scene and on arrival to ED. Patients excluded from this group includes those with bleeding disorders and warfarin and those patients in whom history or mechanism is unclear.
Mild head injury – head injury associated with a brief loss of consciousness (<5minutes), amnesia or both associated with a GCS of 14 or 15
Moderate head injury - head injury associated with a GCS of 9 to 13. Associated with confusion or lethargy, but still able to follow simple commands
Severe head injury – head injury associated with a GCS below 8. This represents a neurosurgical emergency

GLASGOW COMA SCALE

Eye Opening (E)	Best Verbal Response (V)	Best Motor Response (M)
4 = Spontaneous	5 = normal conversation	6 = normal
3 = to voice	4 = disorientated	5 = localizes to pain
2= to pain	3 = incoherent words	4 = withdraws to pain
1 = none	2 = incomprehensible	3 = decorticate (flexion)
	1 = none	2 = decerebrate (extension)
		1 = none

ASSESSMENT AND MANAGEMENT GUIDELINES

Minimal head injury
Patients in this group can be managed conservatively unless there are significant risk factors or clinical deterioration. The patient should be observed until a full neurological assessment is made, including gait assessment.

Mild head injury (GCS 14 or 15)
Most patients with mild head injury make uneventful recoveries. However 2-3% of these patients deteriorate unexpectedly. Risk factors for clinically significant brain injury in these patients include;

1. GCS score <15 at 2 hours post injury time or any decrease in GCS while in ED
2. Suspected open or depressed skull fracture
3. Focal neurological signs
4. Any sign of basal skull fracture
5. Vomiting >2 episodes
6. Ongoing confusion or restlessness
7. Age > 65 years especially if on aspirin, clopidogrel or other antiplatelet agents
8. Post traumatic amnesia > 30 minutes
9. Dangerous mechanism (fall>5 stairs, MVA with ejection, pedestrian struck)
10. Seizure associated with head injury
11. Focal blow to the temporal/parietal region of the head especially with a heavy implement
12. Patient on warfarin or has bleeding disorder (e.g. haemophilia, hepatic failure)
13. Severe persistent headache

CT should therefore be performed on head injured patients with any of the above risk factors. These risk factors also apply to intoxicated patients who sustain head injury regardless of whether the GCS assessment is deemed to be due to intoxication. If there is any doubt about the head CT, then the Radiology Registrar should be contacted to review the study. If the head CT is normal, the following should be assessed.

Mental state and neurological function
Gait and falls risk at home
Reliable person to observe at home

Any concerns regarding the above should prompt senior ED review and input. Upon discharge, a head injury advice sheet should be given to the patient or carer.

Moderate Head Injury (GCS 9-13)
All such patients should have an urgent head CT arranged on arrival. Up to 10% deteriorate and require urgent neurosurgical intervention. This should occur within 1 hour of arrival and this urgency should be communicated to the Radiology Registrar. In addition, the RPAH Trauma Team should be activated. If the head CT is normal and the depressed GCS is deemed to be due to intoxication, the patient may be closely monitored in ED. If there is any evidence of intracranial injury on head CT or persistent neurological dysfunction or confusion despite an apparently normal head CT then neurosurgical consultation should be obtained. If the head CT is normal and the patient recovers to GCS 15 with normal neurological function then assess as per mild head injury.

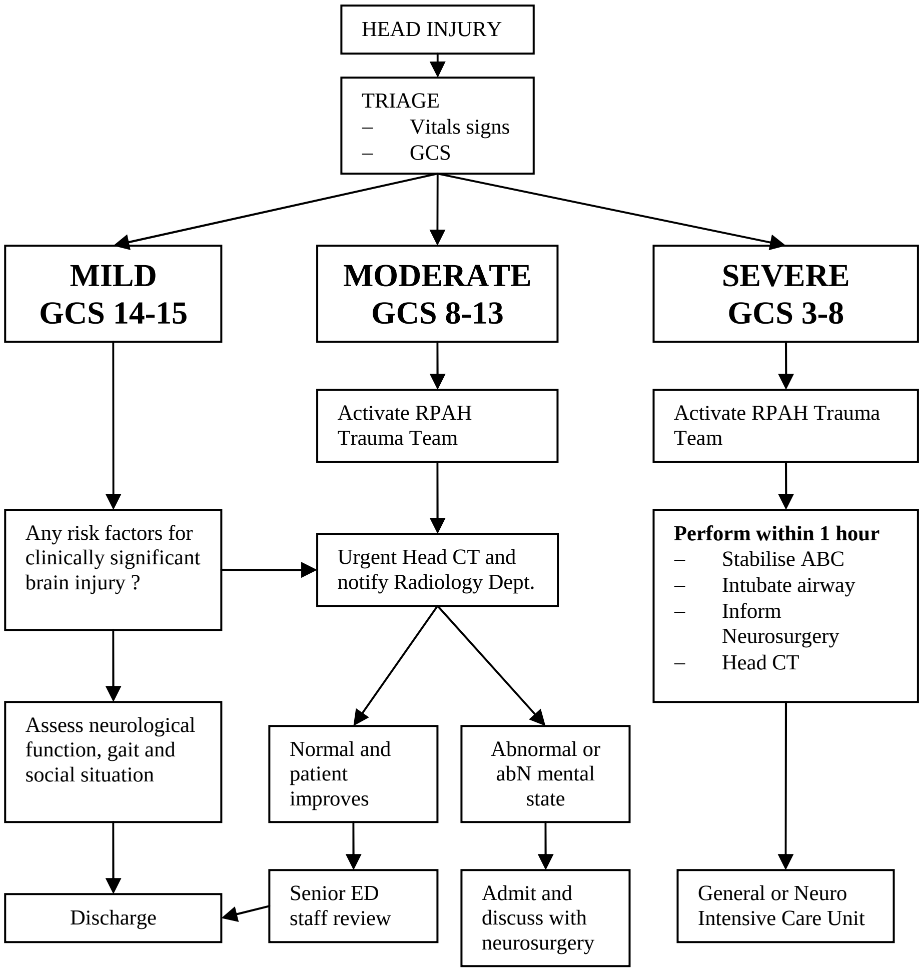
Severe head injury (GCS 3-8)
The RPAH Trauma Team must be activated, patient transferred to the resuscitation bay and stabilised using standard trauma drill. Over half of these patients require some form of neurosurgical intervention. The priorities are to rapidly secure an airway, ensure adequate ventilation and oxygenation and identify and treat any cause of haemorrhage. The patient must be intubated within 10 minutes of arrival and preparations made for head and cervical spine CT within 1 hour of assessment. The preferred method is rapid sequence induction with in line cervical stabilization. To expedite CT imaging and neurosurgical decision making, both the Radiology Registrar and Neurosurgical Registrar are to be notified upon identifying the patient with severe head injury and need for intubation. Whilst preparations are under way for airway intubation, a rapid neurological assessment is made focusing on;

- Glasgow Coma Score (Eye, Voice, Motor)
- Pupillary response
- Symmetry of motor response
- Reflexes

If there is evidence of brain herniation syndrome e.g. unilateral dilated pupils, mannitol 1g/kg IV over 20 minutes should be given as a temporizing measure before definitive neurosurgical intervention
.
Upon airway confirmation, portable monitoring equipment, oxygen and appropriate drugs are assembled. The patient should be transported to CT within 1 hour of ED arrival. The following issues should also be addressed in all severe head injuries;

1. *Adequate ventilation and oxygenation* – Ventilation settings such as respiratory rate, tidal volume and PEEP should be titrated to pCO2 between 30-35mmHg and pO2 >80mmHg. Hyperventilation has not been shown to improve outcomes
2. *Identification and correction of hypotension*. The MAP should be maintained around 90mmHG to optimize cerebral perfusion pressure. Hypotension doubles mortality in severe head injuries – therefore efforts to identify and control haemorrhage must take precedence over other trauma priorities. Treatment for excessive hypertension includes opioids and diuretics. Vasodilators should be avoided as they can worsen intracranial hypertension.
3. *Maintain spinal precautions* - Any patient undergoing head CT for severe head injury should also undergo concurrent cervical spine CT and remain in a hard collar until Neurosurgical review and or Trauma Team tertiary survey
4. *Arrangement for Neuro ICU* or General ICU transfer
5. *Correction of coagulopathy* – this includes the rapid reversal of warfarin with four units of FFP and vitamin K 5-10mg intravenously
6. *Seizure control* and prophylaxis: Phenytoin 1g IV over 20 minutes
7. *Antibiotics* for any open skull fracture or signs of CSF leak
8. Ensure *normothermia, normocarbia* and normoglycemia

SUMMARY OF HEAD INJURY GUIDELINE



RISK FACTORS FOR CLINICALLY SIGNIFICANT BRAIN INJURY

- GCS score <15 at 2 hours post injury time or any decrease in GCS while in ED
- Suspected open or depressed skull fracture
- Focal neurological signs
- Any sign of basal skull fracture
- Vomiting >2 episodes
- Ongoing confusion or restlessness
- Age > 65 years especially if on aspirin, clopidogrel or other antiplatelet agent
- Post traumatic amnesia > 30 minutes
- Dangerous mechanism (fall>5 stairs, MVA with ejection, pedestrian struck)
- Seizure associated with head injury
- Focal blow to the temporal/parietal region of the head especially with a heavy implement
- Patient on warfarin or has bleeding disorder (e.g. haemophilia, hepatic failure)
- Severe persistent headache

ROYAL PRINCE ALFRED HOSPITAL
CERVICAL SPINE IMAGING GUIDELINE FOR ADULT TRAUMA ACTIVATIONS

The following is a set of recommendations for imaging and clearance of the cervical spine in trauma patients. The priorities in cervical spine clearance are firstly to minimize the chances of missed injury and secondly to identify patients who may safely forgo any imaging. These guidelines should always be used in conjunction with clinical judgment based on experience and expertise. The following doctors can clear the cervical spine in a trauma activated patient;

1. Trauma Team Leader
2. ED Registrar/Specialist
3. Surgical Registrar/Specialist
4. Neurosurgical Registrar/Specialist

Timely evaluation of the cervical spine is an important priority, but does not take precedence over resuscitation and surgical stabilisation of the trauma patient. Cervical spine imaging and clearance may be deferred if the patient requires more urgent interventions. When indicated, the cervical collar must remain until adequate imaging is obtained and reported.

INDICATIONS FOR INITIAL CERVICAL SPINE CT
In the following patient populations involved in a trauma team response, initial CT imaging of the cervical spine is strongly recommended, regardless of the C spine series results

- Severe head injury or altered mental state requiring head CT
- Intubated patients
- Focal neurological signs or symptoms and signs referable to the cervical spine
- All patients with multiple injuries undergoing torso/head CT

The Trauma Team Leader must contact the Radiology Registrar regarding the request for CT cervical spine. The patient must be maintained with spinal precautions until the Radiology Registrar/Radiologist has reported the study.

NEUROLOGICAL SIGNS OR SYMPTOMS REFERRABLE TO THE CERVICAL SPINE
If the patient has neurological signs or symptoms referable to a potential cervical spine injury, the neurosurgical registrar on call is notified as soon as possible. Imaging and management priorities in these situations will need to be decided on a case by case basis. Referral should not be deferred unless other injuries make this necessary.

CLEARANCE OF CERVICAL SPINE FOR PATIENTS NOT UNDERGOING CT

Patients who do not have indications for initial cervical spine CT should be evaluated as follows. Those patients who are or have;

- No dangerous mechanism (dangerous mechanism = fall >3m or MVA >60km/hr, motorcyclist, ejection or rollover, sporting or diving injuries with axial load to head)
- < 65 years of age
- Alert and not intoxicated
- No focal neck pain or tenderness on examination
- No focal back pain, tenderness or deformity on log roll examination
- No focal neurological signs or symptoms
- No other injuries that may distract the patients attention from the neck

May have their cervical collar removed and range of motion tested by asking the patient to
move the neck from side to side. If the patient has full range of motion to 45 degrees lateral rotation without focal pain or tenderness, then at this point the cervical spine may be clinically cleared.

Patients who do not fulfill these criteria should undergo 3 view cervical spine radiographs. In such patients, cervical spine immobilization with a hard collar remains until all the following criteria have been met:

1. The Trauma Team Leader or the Emergency Staff Specialist or Radiologist/Radiology registrar has reviewed the C spine series.
2. The C spine series is adequate and normal
3. The patient is alert and cooperative
4. No significant ongoing focal midline neck pain or tenderness
5. No neurological signs or symptoms referable to the cervical spine

If there are any suspicious abnormalities on cervical spine radiographs, extensive degenerative changes or inadequate visualization of the C7/T1 junction despite swimmers view then cervical spine CT should be arranged.

If there is ongoing focal midline neck pain or tenderness despite a completely normal and adequate X ray or CT in the alert cooperative patient, then flexion extension views should be performed. This will reliably diagnose cervical spine subluxation suggestive of ligamentous instability. These studies need to be supervised by a doctor to monitor for evidence of neurological signs or symptoms during the study. Flexion extension views are contraindicated in the acute setting if the patient has:

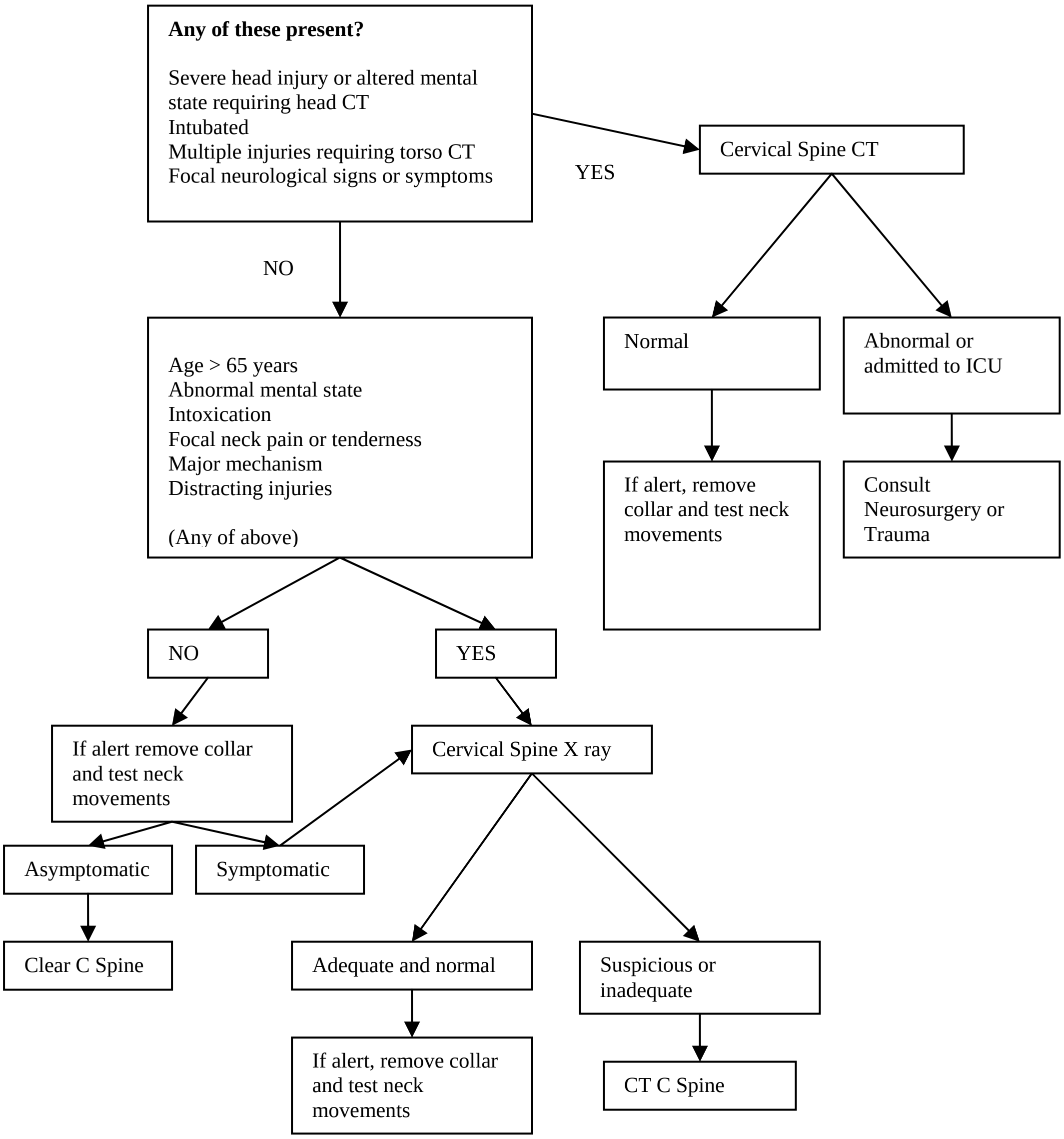
1. Altered mental state
2. Neurological signs or symptoms referable to the C spine
3. Fracture seen on initial C spine X ray or CT

PATIENTS WITH ALTERED MENTAL STATE OR ADMITTED TO INTENSIVE CARE

Patients in whom return to normal mental state is expected within 24 hours (e.g. intoxication) should be maintained with spinal precautions until the patient has normal mental state. The patient should then be assessed as above.

Patients in whom decreased alertness is expected to last >24 hours should be maintained with spinal precautions until assessment by the neurosurgical registrar and appropriate imaging obtained and reported. An MRI or fluoroscopic flexion extension studies may be indicated depending on clinical circumstances.

ALGORITHM FOR INITIAL IMAGING OF CERVICAL SPINE IN TRAUMA



Dangerous Mechanism
MVA >60km/hr, ejection, rollover, motorcyclist
Fall >3m
Axial load to head from sporting or diving injury

Distracting injury
Proximal long bone or pelvic fractures
Chest or abdominal injuries
Major burns, degloving or lacerations

Admission of trauma patients

All trauma patients who require admission to hospital following Trauma Team Activation are to be admitted under the Trauma Surgeon of the day until the tertiary survey has been conducted and documented in the patient's notes (usually within 24 hours). Patient's care will normally be transferred to the most appropriate subspecialty team according to their most significant injury at the time, i.e. that requiring active intervention or likely to require long-term care in the absence of other active management issues. The Trauma Unit may be called upon to assist with these decisions if required and should there be a conflict, the final decision will be made by the Director of Trauma.

Jeffrey Petchell FRACS
Director of Trauma Services

Chris Byrne FRACS
Director of Trauma Services

5

Contact details

Trauma Directors

Michael Dinh
Staff Specialist
Emergency Department
RPAH
Ph. 95156111 #
or contact switchboard and ask for mobile

Chris Byrne
Colorectal Surgeon
RPAH
Ph. 95156111 #
or contact switchboard and ask for mobile

Jeffery Petchell
Orthopaedic Surgeon
RPAH
Ph. 95172630 (consulting room)
or contact switchboard and ask for mobile

Trauma Clinical Nurse Consultant

Liz Leonard
Ph. 95156111 #88126
Hours: 0730-1615
Monday / Tuesday / Wednesday

Amanda Stack
Ph. 95156111 #88126
Hours: 0730-1615
Thursday / Friday

Trauma Data Manager

Sue Roncal
Ph. 95156111 #81322
Monday-Friday

Working together to lessen the impact of cancer

5 August 2014

A/Prof Michael Dinh
Emergency Department
Royal Prince Alfred Hospital
Missenden Road
Camperdown NSW 2050

Dear A/Prof Dinh,

NSW Population & Health Services Research Ethics Committee

AU RED Reference: HREC/14/CIPHS/38

Cancer Institute NSW reference number: 2014/06/537

Project Title: **Demand for Emergency Service Trends IN Years 201015 (DESTINY10.15): A population based study of Emergency Department utilisation and length of stay in New South Wales**

Thank you for your correspondence dated 30 July 2014 responding to a request for further information/clarification of the above referenced study, submitted to the NSW Population & Health Services Research Ethics Committee (Executive). The Committee reviewed your response at its meeting held on 4 August 2014 and I am pleased to inform you that full ethical approval has been granted.

This approval is conditional upon the following:

1. The study must also receive final approval from the NSW Aboriginal Health & Medical Research Council Ethics Committee.

The NSW Population & Health Services Research Ethics Committee has granted a waiver of the usual requirement for the consent of the individual to the use of their health information in a research project, in line with the State Privacy Commissioner's Guidelines for Research and the Health Records and Information Privacy Act 2002 (NSW).

The documents reviewed and approved include:

- NSW ethics revision cover letter, dated 24 July 2014
- NSW National Ethics Application Form, v2.1, submission code AU/1/DD48112, dated 22 July 2014
- Protocol, Version 1.0, clean, dated 3 July 2014
- Protocol, Version 1.0, tracked, dated 3 July 2014
- CHeReL Letter of Feasibility, dated 20 March 2014
- CHeReL Application for Data
- Data Custodian Sign off, NSW Emergency Department Data Collection (EDDC), dated 26 March 2014
- NSW Emergency Department Data Collection – variable list
- NSW Health Privacy form
- AHMRC letter of support, dated 24 July 2014

Approval is now valid for the following sites:

- Royal Prince Alfred Hospital, Camperdown
- The George Institute for Global Health, Sydney

The NSW Population & Health Services Research Ethics Committee has been accredited by the NSW Ministry of Health to provide single ethical and scientific review of research proposals conducted within the NSW public health system.

The Committee is a joint initiative of the Cancer Institute NSW and NSW Ministry of Health. The Committee has been constituted and operates in accordance with the National Health and Medical Research Council's *National Statement on Ethical Conduct in Human Research (2007)* and relevant legislation and guidelines.

Please note that ethical approval is valid for **5 years**, conditional on the following:

- Principal investigators will immediately report anything which might warrant a review of ethical approval of the research, including unforeseen events that might affect continued ethical acceptability.
- Proposed amendments to the research proposal or conduct of the research which may affect the ethical acceptability of the research are to be provided to the NSW Population & Health Services Research Ethics Committee for review.
- The NSW Population & Health Services Research Ethics Committee will be notified giving reasons, if the research is discontinued before the expected date of completion.
- The Principal Investigator will provide a progress report to the NSW Population & Health Services Research Ethics Committee annually and at the completion of the study.

Your first progress report will be due on 05/08/2015 and the duration of approval is until 05/08/2019, after which time a new submission to the Ethics Committee will be required.

You are reminded that this letter constitutes *'ethical approval'* only. This research project must not commence at a site until separate authorisation from the Chief Executive or delegate of that site has been obtained. It is your responsibility to forward a copy of this letter together with any approved documents as enumerated above, to all site investigators for submission to the site's Research Governance Officer. Where relevant, copies will also need to be provided to the CHeReL and the data custodian.

For further information about the NSW Population & Health Services Research Ethics Committee, please refer to our website www.cancerinstitute.org.au/research.

Should you have any queries about the ethical review of your research proposal, please contact me on 02 8374 3562 or email ethics@cancerinstitute.org.au.

Yours sincerely,

BTurner

Dr Brie Turner
Ethics and Research Governance Manager
Cancer Institute NSW

ADDRESS FOR ALL CORRESPONDENCE
RESEARCH DEVELOPMENT OFFICE
ROYAL PRINCE ALFRED HOSPITAL
CAMPERDOWN NSW 2050

NSW GOVERNMENT | Health
Sydney
Local Health District

TELEPHONE: (02) 9515 6766
FACSIMILE: (02) 9515 7176
EMAIL: lesley.townsend@email.cs.nsw.gov.au
REFERENCE: X12-0064 & HREC/12/RPAH/104

7 May 2012

Mr K Cornwall
Department of Bone & Connective Tissue
Trauma Office
Level 10, Building 75
Royal Prince Alfred Hospital

Dear Mr Cornwall,

Re: Protocol No X12-0064 & HREC/12/RPAH/104 - "Health outcomes after trauma at a New South Wales major trauma centre – A Follow up study"

The Executive of the Ethics Review Committee, at its meeting of 26 April 2012, considered your correspondence of 10 April 2012. In accordance with the decision made by the Ethics Review Committee, at its meeting of 14 March 2012, approval is granted to proceed.

The proposal meets the requirements of the *National Statement on Ethical Conduct in Human Research*.

This approval includes the following:

- Protocol (Version 1.0, 1 March 2012)
- Brochure (Version 2, 10 April 2012)
- Participant Consent Form (Version 2.0, 10 April 2012)
- Letter to patients (Version 3.0, 10 April 2012)
- Telephone Scripts for Trauma Follow up Study (Version 3.0, 10 April 2012)
- Patient Interview (Version 2.0, April 2012)

You are asked to note the following:

- The study is authorised to be conducted at the following site(s):
    - Royal Prince Alfred Hospital
- This approval is valid for four years, and the Committee requires that you furnish it with annual reports on the study's progress beginning in May 2013. If recruitment is ongoing at the conclusion of the four year approval period, a full re-submission will be required. Ethics approval will continue during the re-approval process.
- You must immediately report anything which might warrant review of ethical approval of the project in the specified format, including unforeseen events that might affect continued ethical acceptability of the project.
- You must notify the HREC of proposed changes to the research protocol or conduct of the research in the specified format.
- You must notify the HREC, giving reasons, if the project is discontinued before the expected date of completion.
- You are responsible for the following:
    - arranging a Criminal Record Check and a SLHD identity pass for any researcher who is not employed by the Sydney Local Health District. You should contact the Ethics Officer on 02 9515 7899 for advice on this matter, and
    - if appropriate, informing the study sponsor that this human research ethics committee (HREC) has been accredited by the NSW Department of Health as a lead HREC under the model for single ethical and scientific review and is constituted and operates in accordance with the National Health and Medical Research Council's *National Statement on Ethical Conduct in Human Research* and the *CPMP/ICH Note for Guidance on Good Clinical Practice*.
- If you or any of your co-investigators are University of Sydney employees or have a conjoint appointment, you are responsible for informing the University's Risk Management Office of this approval, so that you can be appropriately indemnified.

- Where appropriate, the Committee recommends that you consult with your Medical Defence Union to ensure that you are adequately covered for the purposes of conducting this study.

Yours sincerely,

Lesley Townsend

Lesley Townsend
Executive Officer
Ethics Review Committee (RPAH Zone)

Research Governance Officer
SLHD (RPAH Zone)

HERC\EXCOR\12-05

24 April 2015

Dr Jenny Miu
Institute of Trauma and Injury Management (ITIM)
Agency for Clinical Innovation
Sage Building, Level 4, 67 Albert Ave
Chatswood, NSW 2067

Dear Dr Miu,

NSW Population & Health Services Research Ethics Committee

AU RED Reference: LNR/15/CIPHS/16

Cancer Institute NSW reference number: LNR 2015/04/036

Project Title: Injury trends and mortality in patients with major trauma in NSW

Thank you for your Low and Negligible Risk application submitted to the NSW Population & Health Services Research Ethics Committee. The Committee has reviewed your documentation and I am pleased to advise you that full ethical approval has been granted.

The Committee reviewed and approved the following documents:

- Submission Checklist
- National Ethics Application Form LNR Version 2 (2011), submission code AU/6/59AD115, dated 12 March 2015
- Protocol, Version 1, dated 24 January 2015
- Data Custodian approval, NSW Trauma Registry, 4 March 2015
- NSW Trauma Registry variables checklist
- NSW Health Privacy Form

Approval is now valid for the following sites:

- NSW Institute of Trauma and Injury Management, Agency for Clinical Innovation, Sydney
- University of Sydney, NSW

The NSW Population & Health Services Research Ethics Committee has been accredited by the NSW Ministry of Health to provide single ethical and scientific review of research proposals conducted within the NSW public health system.

The Committee is a joint initiative of the Cancer Institute NSW and NSW Ministry of Health. The Committee has been constituted and operates in accordance with the National Health and Medical Research Council's *National Statement on Ethical Conduct in Human Research (2007)* and relevant legislation and guidelines.

Please note that ethical approval is valid for **5 years**, conditional on the following:

- Principal investigators will immediately report anything which might warrant a review of ethical approval of the research, including unforeseen events that might affect continued ethical acceptability.
- Proposed amendments to the research proposal or conduct of the research which may affect the ethical acceptability of the research are to be provided to the NSW Population & Health Services Research Ethics Committee for review.
- The NSW Population & Health Services Research Ethics Committee will be notified giving reasons, if the research is discontinued before the expected date of completion.
- The Principal Investigator will provide a progress report to the NSW Population & Health Services Research Ethics Committee annually and at the completion of the study.

Your first progress report will be due on 24/04/2016 and the duration of approval is until 24/04/20120, after which time a new submission to the Ethics Committee will be required.

You are reminded that this letter constitutes *'ethical approval'* only. This research project must not commence at a site until separate authorisation from the Chief Executive or delegate of that site has been obtained. It is your responsibility to forward a copy of this letter together with any approved documents as enumerated above, to all site investigators for submission to the site's Research Governance Officer. Where relevant, copies will also need to be provided to the CHeReL and the data custodian.

For further information about the NSW Population & Health Services Research Ethics Committee, please refer to our website www.cancerinstitute.org.au/research.

Should you have any queries about the ethical review of your research proposal, please contact me on 02 8374 3562 or email ethics@cancerinstitute.org.au.

The NSW Population & Health Services Research Ethics Committee wishes you well in your research endeavours.

Yours sincerely,

B Turner

Dr Brie Turner
Ethics and Research Governance Manager
Cancer Institute NSW

Major trauma mortality in rural and metropolitan NSW, 2009–2014: a retrospective analysis of trauma registry data

Michael M Dinh[1,2], Kate Curtis[3], Rebecca J Mitchell[4,5], Kendall J Bein[2], Zsolt J Balogh[6,7], Ian Seppelt[8,9], Colin Deans[10], Rebecca Ivers[11,12], Saartje Berendsen Russell[2,13], Oran Rigby[14]

The known Trauma systems facilitate the timely treatment of major trauma patients at specialised centres, and this approach has reduced trauma-related mortality in Australia and overseas. Trauma in rural areas, however, has been associated with higher mortality.

The new Trauma system changes introduced to New South Wales since 2009 may be associated with a decline in crude and adjusted inpatient mortality after major trauma in rural and regional locations.

The implications Better transfer of rural patients, retrieval networks, and improved trauma care at major trauma centres may be benefiting severely injured patients from rural and regional locations in NSW.

Abstract

Objective: To determine trends in crude and risk-adjusted mortality for major trauma patients injured in rural or metropolitan New South Wales, 2009–2014.

Design: A retrospective analysis of NSW statewide trauma registry data.

Participants: Adult patients (aged 16 years or more) who presented with major trauma (Injury Severity Scores greater than 15) to a NSW hospital during 2009–2014.

Main outcome measures: The main covariate of interest was geographic location of injury (metropolitan *v* rural/regional areas). Inpatient mortality was analysed by multivariable logistic regression.

Results: Data for 11 423 eligible patients were analysed. Inpatient mortality for those injured in metropolitan locations was 14.7% in 2009 and 16.1% in 2014 ($P = 0.45$). In rural locations, there was a statistically significant decline in in-hospital mortality over the study period, from 12.1% in 2009 to 8.7% in 2014 ($P = 0.004$). Risk-adjusted mortality for those injured in a rural location was lower in 2013 than during 2009, but remained stable for those injured in metropolitan locations.

Conclusion: Crude and risk-adjusted mortality after major trauma have remained stable in those injured in metropolitan areas of NSW between 2009 and 2014. The apparent downward trend in mortality associated with severe trauma in rural/regional locations requires further analysis.

Injury causes significant physical and psychological disability around the world,[1,2] and cost-effective systems of care are important for optimising patient outcomes and recovery. Trauma systems facilitate the timely treatment of severely injured patients, and this approach has reduced mortality among trauma patients in several Australian states[3,4] and overseas.[5,6] A system for trauma care was introduced in New South Wales in 1991, and the first analyses of major trauma outcomes in NSW were conducted in 2012.[7,8] It was found that a survival benefit was associated with definitive care at designated major trauma centres located in NSW metropolitan areas.[8]

A number of factors may influence outcomes for trauma patients in rural and regional areas, particularly the sparse population density and the vast transport distances for many rural and regional trauma patients. Studies from other parts of Australia have indicated that rural trauma patients have poorer outcomes than metropolitan trauma patients, and it is recognised that road accidents in rural and remote locations are associated with higher risks of death and severe injury.[9,10] The NSW Trauma Minimum Dataset now includes additional details on injuries, including those for a number of regional centres,[11] allowing more detailed analyses of outcomes according to the geographic location of injuries incurred after 2009.

This change was particularly relevant because the revised NSW State Trauma Plan was implemented in 2009, formalising rural and regional referral networks for each of the seven adult major trauma centres.[12] The aim of these networks was to facilitate the timely transfer of severely injured patients from sparsely populated rural and remote areas of NSW to major trauma centres in metropolitan areas along the east coast. We assessed and compared trends in crude and risk-adjusted mortality between 2009 and 2014 in the context of these changes, designed to improve trauma care and patient outcomes in NSW.

Methods

NSW is the most populous Australian state, with a population of 7.5 million in 2014 and an area of 809 000 km^2. Around 70% of the population live in metropolitan areas on the eastern seaboard.[13]

We undertook a retrospective analysis of statewide trauma registry data. The statewide trauma registry was established and is maintained by the NSW Institute of Trauma and Injury Management; it receives data from seven adult major trauma centres and ten regional trauma centres.[11] According to the standards of the American College of Surgeons,[14] major trauma centres in NSW are equivalent to level 1 designated trauma centres (the top level), and regional trauma centres are equivalent to level 2 or 3 centres.

Adult patients (aged 16 years or more) were included in our analysis if they presented to a NSW hospital between 1 January 2009 and 31 December 2014, and their Injury Severity Score (ISS) was greater than 15.

Trauma centres that did not submit data for the entire study period were excluded. Patients were also excluded if the postcode of the site

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where they were injured was unknown or outside NSW, as were those who were dead on arrival at hospital. Duplicate records for patients who had been transferred between hospitals were identified, and the second and subsequent records excluded if the referral hospital provided trauma data to the NSW Trauma Registry.

Basic demographic characteristics, the mechanism of injury, vital signs on arrival at hospital, length of stay in hospital, and in-hospital mortality were analysed. Injuries were classified according to the Abbreviated Injury Scale (AIS). The AIS codes injuries according to their anatomic location (head, neck, chest, abdomen, lower limb, upper limb, external) and assigns a severity score, ranging from 1 to 6, according to the likelihood of death and disability. Severe injuries in this study were defined by AIS scores of 3 or more.[15] The ISS, used to assess the overall severity of injury, was calculated by summing the squares of the AIS severity scores for the three most severely injured body regions. Major trauma was defined as an ISS greater than 15. Measures of hospital resource use included inter-hospital transfer, and the first major trauma procedures recorded by the referring hospital, ambulance or retrieval services, or trauma centre. The geographic location where the patient sustained their injury was identified by postcode, and categorised as metropolitan, inner regional, or outer regional/remote according to the Australian Statistical Geography Standard Remoteness Structure.[16] As the number of deaths in outer regional/remote regions was small, all non-metropolitan postcodes were merged as rural/regional for multivariable analyses.

The primary outcome for our study was in-hospital mortality after major trauma, analysed according to the geographic location of the injury.

Statistical analyses

Descriptive statistics for baseline characteristics and crude in-hospital mortality are reported. Year-by-year differences and trends in crude in-hospital mortality were compared in χ^2 and Cochran–Armitage linear trend tests. Risk-adjusted mortality trends were assessed in logistic regression models stratified by geographic location of the injury and adjusted for age, injury severity, intensive care unit admission, and year of admission. Variables were included in models according to the results of preceding univariate analyses ($P < 0.1$), or if they had been identified as influencing mortality risk in adult injury patients by previous studies.[8] Adjusted odds ratios (ORs) for inpatient mortality in separate rural and metropolitan location regression models were plotted on a line chart to identify trend in ORs relative to the reference year, 2009. Multivariable adjusted trends were determined by changing the year predictor variable to a linear continuous variable for logistic regression modelling and non-parametric generalised additive models (GAM). Analyses were performed in SAS Enterprise Guide 6.1 (SAS Institute).

Ethics approval

Approval was obtained from the NSW Population Health Services and Research Ethics Committee (reference, 2015/04/036).

Results

Study population

A total of 18 652 patients were identified in the trauma registry data for the period 2009–2014. After the exclusions described in the Methods, data for 11 423 adult patients with an ISS greater than 15 from seven adult major trauma centres and three regional trauma centres were analysed (Appendix).

Box 1 compares the demographic characteristics of rural/regional (combined inner, outer regional and remote injury locations) and metropolitan major trauma patients, and the clinical characteristics of their injuries. With respect to location of injury, 8878 patients (77.7%) were in metropolitan locations, 1855 (16.2%) in inner regional locations, 601 (5.3%) in outer regional locations, and 89 (0.8%) in remote locations. The mean age of the patients was 53.5 years (SD, 23.1); 71.9% of the patients were men. The most common mechanisms of injury were falls (44.3%), road trauma (37.6%) and blunt assault (5.9%); penetrating injuries accounted for 3.6% of all cases.

The distribution of ages of rural/regional trauma patients, compared with metropolitan patients, was shifted to younger age groups. The proportions of head, chest, spinal, and lower limb severe injuries were higher for rural/regional trauma patients, consistent with the higher proportion of road trauma cases in this patient population (Box 1).

Inpatient major trauma mortality

Almost half of major trauma inpatient deaths (46.6%) occurred within 24 hours of admission, a further 30% occurred during the first week of admission, and 23.4% occurred after the second week of admission. The overall inpatient mortality rate for major trauma was 14.1% in 2009 and 14.5% in 2014, with no significant trend (Cochran–Armitage test, $P = 0.66$). There was no difference in overall inpatient mortality between admissions to major trauma and non-major trauma centres (14.0% *v* 13.0%; $P = 0.47$). For those injured in metropolitan locations, inpatient mortality was 14.7% in 2009 and 16.1% in 2014 (Cochran–Armitage test, $P = 0.45$). Major trauma in rural/regional locations was associated with a statistically significant decrease in in-hospital mortality over this period, from 12.1% in 2009 to 8.7% in 2014 (Cochran–Armitage test, $P = 0.004$). When rural/regional location was further stratified, major trauma mortality in inner regional locations decreased from 12.7% in 2009 to 10.4% in 2014 ($P = 0.07$); for outer regional/remote locations, it decreased from 10.3% in 2009 to 4.0% in 2014 ($P = 0.005$).

Box 2 shows the trend in risk-adjusted mortality for rural/regional and metropolitan injuries, compared with the reference year 2009. The adjusted OR for in-hospital mortality associated with rural/regional injuries was lower in 2013 (OR, 0.5; 95% CI, 0.3–0.8) and 2014 (OR, 0.6; 95% CI, 0.4–1.0) than in 2009. Mortality among rural patients declined by an average of 12% per year when year was analysed as a linear predictor (OR, 0.88; 95% CI, 0.81–0.96; $P = 0.004$); non-parametric GAM analysis indicated that this decline was statistically significant (multivariable GAM, $P = 0.007$). In contrast, there was no trend in risk-adjusted mortality for injuries in metropolitan locations (multivariable GAM, $P = 0.25$).

Mode of arrival and inter-hospital transfer

For the 2292 major trauma patients injured in a rural location and admitted to a major trauma centre, there was no change between 2009 and 2014 in the proportion who arrived directly (not transferred from another hospital) at a major trauma centre from a rural location (38.7% *v* 36.7%; Cochran–Armitage test, $P = 0.96$). There was an increase in the proportion who arrived at a major trauma centre by ambulance from a rural location (26.2% *v* 60.6%; $P < 0.001$), and a decline in the median time from injury to first trauma procedure from 276 min (interquartile range [IQR], 104–1420) in 2010 to 95 min (IQR, 48–495) in 2014 ($P < 0.001$).

1 Baseline demographic data, clinical characteristics, and in-hospital mortality for 11 423 major trauma patients (Injury Severity Score > 15), New South Wales Trauma Registry, 2009–2014, by geographic location of injury

	Metropolitan NSW		Rural/regional NSW		*P*
Total number of patients	8878		2545		
Age group					< 0.001
16–24 years	1191	13.4%	473	18.6%	
25–44 years	2108	23.7%	735	28.9%	
45–64 years	2091	23.6%	678	26.7%	
64–84 years	2441	27.5%	565	22.2%	
> 84 years	1047	11.8%	94	3.7%	
Sex					
Men	6294	70.9%	1920	75.4%	
Mechanism of injury					< 0.001
Road trauma	2994	33.7%	1298	51.0%	
Falls	4276	48.2%	713	28.0%	
Penetrating trauma	347	3.9%	72	2.8%	
Blunt assaults	527	5.9%	150	5.9%	
Burns	180	2.0%	41	1.6%	
Other	554	6.3%	269	10.6%	
Injury Severity Score (ISS)					0.23
15–24	5119	57.7%	1428	56.1%	
25–49	3518	39.6%	1036	40.7%	
≥ 50	241	2.7%	81	3.2%	
Severe injury site (AIS > 2)					
Head	5128	57.8%	1266	49.7%	< 0.001
Chest	3028	34.1%	1080	42.4%	< 0.001
Abdomen	855	9.6%	275	10.8%	0.08
Spine/vertebral column	997	11.2%	413	16.2%	< 0.001
Upper limb	104	1.2%	48	1.9%	0.005
Lower limb	1342	15.1%	496	19.5%	< 0.001
External	143	1.6%	32	1.2%	0.20
Mode of arrival to initial hospital					< 0.001
Ambulance	7310	87.3%	1234	58.4%	
Helicopter	547	6.5%	692	32.8%	
Fixed wing aircraft	6	0.1%	47	2.2%	
Private vehicle	470	5.6%	133	6.3%	
Other	42	0.5%	7	0.3%	
Inpatient deaths					
2009 (*N* = 1790)	209	14.7%	45	12.1%	0.19
2010 (*N* = 1749)	207	15.4%	49	12.1%	0.10
2011 (*N* = 1808)	216	15.4%	39	9.6%	0.003
2012 (*N* = 1895)	206	14.5%	41	8.7%	0.002
2013 (*N* = 2062)	250	15.2%	26	6.2%	< 0.001
2014 (*N* = 2119)	266	16.1%	41	8.7%	< 0.001

AIS = Abbreviated Injury Scale score. *N* = Number of major trauma cases for year. ◆

Discussion

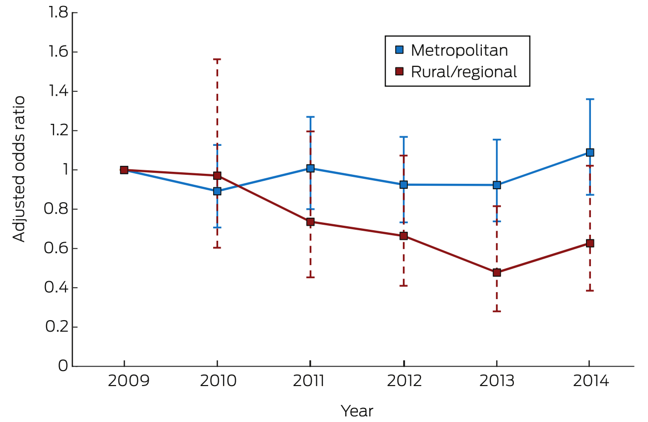
We found that overall inpatient mortality after major trauma remained steady between 2009 and 2014, but crude mortality declined among patients severely injured in rural and regional NSW. There was also a reduction in risk-adjusted mortality associated with rural location of injury. Comparison of data on crude inpatient mortality identified that this trend was most marked for injuries incurred in outer regional and remote locations.

These findings could be explained by a number of factors. Firstly, the establishment of trauma referral networks may have resulted in more efficient transfers between rural facilities and major trauma centres. We found that the time to first trauma procedure for patients from rural areas had declined since 2009. The NSW Ambulance Service trauma bypass protocol (protocol T1), revised in 2008, allowed for an increase in acceptable transfer time between the scene of the injury and arrival at the nearest designated trauma centre from 30 minutes to one hour.[17] In addition, the introduction of the Rapid Launch Trauma Coordinator function in the NSW Ambulance Aeromedical Control Centre aimed to improve the early identification of major trauma incidents by monitoring emergency 000 calls to ensure that specialist pre-hospital resources are activated as early as possible. Both factors may have contributed to the steady increase in direct ambulance arrivals at major trauma centres from rural locations between 2009 and 2014. This has occurred although the proportion of inter-hospital transfers from rural and regional hospitals to major trauma centres was unchanged. It is unclear whether direct or secondary transfer from a rural hospital or direct transport to a major trauma centre is associated with improved survival. A 2011 systematic review of 36 observational studies found no difference, although most investigations were subject to potential referral bias, in that they excluded deaths from the data for referring hospitals.[18]

Secondly, improved outcomes for severely injured rural patients may have resulted from improved clinical care in regional trauma centres and rural referral centres. A core mission of the NSW Institute for Trauma and Injury Management over the past decade has been to coordinate and improve access to clinical expertise and education resources in these centres.[12] This approach included employing regional trauma nurse coordinators, which achieved improved education, case management, data collection and audit capabilities. An American study of 18 rural level 3 and 4 trauma centres found that a rural trauma education course alone reduced the time to transfer of severely injured patients.[19]

Thirdly, the reduction in major trauma mortality in outer regional and remote locations underscores the importance of road safety initiatives for preventing deaths and critical injuries. The reductions reported here mirror the 11% drop in the rate of road accident deaths (per 100 000 population) in very remote locations between 2008 and 2012, compared with reductions of 0.7% in inner regional and 0.9% in metropolitan areas.[20] The National Road Safety Strategy highlights the need to prioritise improving high risk rural and urban roads, vehicle safety standards, and safety for vulnerable road users.[20] Nevertheless, rural road deaths continue to occur at two to three times the national average because of the longer travel distances, higher vehicle speed zones, and the greater likelihood of head-on collisions and vehicle rollovers than in more urban locations.[21] This problem requires further attention and investment from all levels of government.

2 Risk-adjusted odds ratios for mortality following major trauma, New South Wales, 2009–2014, stratified by geographic location of injury*



* The reference year is 2009. Estimates and 95% confidence intervals can be compared with the reference year, but not between rural/regional and metropolitan locations. ◆

The lack of overall improvement in major trauma mortality in metropolitan NSW since the 2012 study by Curtis and colleagues[8] is concerning. These authors had reported that overall mortality for NSW patients (rural and metropolitan) with an ISS greater than 15 had declined from 15.0% in 2003 to 12.9% in 2007. Mortality among trauma patients appears to have returned to around 15%, highlighting the ongoing need for quality improvements in the major trauma system in NSW, including regionalisation of trauma centres[22] and models of care that sustainably manage the growing proportion of older major trauma patients.[23] We found that the overall mortality of patients with an ISS greater than 12 during 2013–14 (all centres submitted data during this period for patients with an ISS over 12) was 11.1%, similar to the 11% reported by the Victorian population-based trauma registry for 2013–14.[24]

It remains to be seen whether risk-adjusted mortality associated with trauma in rural/regional areas continues to fall. Despite the downward trend in Box 2, the decrease was statistically significant only for 2013. The relatively small sample of patients in the rural/regional cohort may explain the lack of statistical significance for other years, as confidence limits for estimates were narrower when rural and regional case numbers were higher. Further analyses that include all years with complete data, including physiological data from rural/regional trauma centres, are needed to assess these trends, as is further risk adjustment modelling, consistent with analyses by other trauma registries.[24]

We also acknowledge other limitations of our study. Firstly, seven regional trauma centres did not submit data to the statewide trauma registry until after 2012, and were therefore not included in our study. Data for people who died at the scene of an injury were also excluded, and this may have biased our assessment of rural trauma mortality. Secondly, formal risk adjustment of inpatient mortality according to physiologic parameters was not possible, as vital signs data were not recorded for almost 30% of all cases in the trauma registry. Risk adjustment is important in order to correct for possible differences between locations and facilities in patient characteristics, as well as in mechanisms of injury, age, and physiological parameters. We utilised admission to an intensive care unit as a proxy marker for physiological abnormality, but the risk adjustment models reported here are not comparable with those of the Australian Trauma Registry or with similar studies used to benchmark performance of trauma systems across different locations and facilities.[25] Finally, the period 2009–2012 saw the transition from individual hospital-based trauma registries to a uniform statewide registry designed to streamline data collection, auditing and research across all designated trauma centres. Some of the problems of incomplete data (ie, trauma centres unable to submit data for the full period) may be explained by this transition period.

As the purpose of our study was to evaluate in-hospital mortality and overall trauma system performance and trauma centre care, we analysed only patients who survived to hospital presentation and excluded those who died at the scene of the injury or were declared dead on arrival. These deaths, however, would be reflected in the overall road toll statistics, which have also documented a decline in mortality in NSW.[20] Taken together, the results of our analysis and the declining rural road toll favour our interpretation that overall trauma mortality has declined markedly in rural areas since 2009.

In conclusion, crude and risk-adjusted inpatient mortality associated with major trauma has remained stable for people injured in metropolitan areas of NSW since 2009. The reduction in risk-adjusted mortality in rural and regional NSW is encouraging, but further analyses will be appropriate when data from other NSW regional trauma centres become available.

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Competing interests: No relevant disclosures.

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Manuscript Draft

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Title: AGE-RELATED TRENDS IN INJURY AND INJURY SEVERITY PRESENTING TO EMERGENCY DEPARTMENTS IN NEW SOUTH WALES AUSTRALIA: IMPLICATIONS FOR MAJOR INJURY SURVEILLANCE AND TRAUMA SYSTEMS

Article Type: Full length article

Keywords: Injury; Emergency Department; Trauma.

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Abstract: Objectives: To describe population based trends and clinical characteristics of injury related presentations to Emergency Departments (EDs).
Design and Setting: A retrospective, descriptive analysis of de-identified linked ED data across New South Wales, Australia over five calendar years, from 2010 to 2014.
Participants: Patients were included in this analysis if they presented to an Emergency Department and had an injury related diagnosis. Injury severity was categorised into critical (triage category 1-2 and admitted to ICU or operating theatre, or died in ED), serious (admitted as an in-patient, excluding above critical injuries) and minor injuries (discharged from ED).
Main outcome measures: The outcomes of interest were rates of injury related presentations to EDs by age groups and injury severity.
Results: A total of 2.09 million injury related ED presentations were analysed. Minor injuries comprised 85%, and 14.1% and 1% were serious and critical injuries respectively. There was a 15.8% per annum increase in the rate of critical injuries per 1000 population in those 80 years and over, with the most common diagnosis being head injuries. Around 40% of those with critical injuries presented directly to a major trauma centre.
Conclusion: Critical injuries in the elderly have risen dramatically in recent years. A minority of critical injuries present directly to major trauma centres. Trauma service provision models need revision to ensure appropriate patient care. Injury surveillance is needed to understand the external causes of injury presenting to hospital.

Suggested Reviewers:

TO: 27th May 2016

Editor-in-Chief

Injury

RE: Manuscript submission

Dear Editor,

Thank you for reviewing our work. It is the first population based analysis of injury related presentations to New South Wales Emergency Departments using a state-wide Emergency Department Registry between 2010 and 2014. It aims to analyse demographic trends and clinical characteristics of those patients presenting with injuries to help inform future health policy and improve trauma systems of care.

This article is part of the DESTINY project which aims to understand the drivers of Demand for Emergency Services Trends in Years 2010-14 in NSW. All authors have contributed to the study design, data collection, analysis and interpretation, writing the manuscript and the decision to submit.

Our paper has not been submitted or published elsewhere and we feel this should be published in Injury because of the national significance of emergency department demand and it highlights the rapidly rising rate of injury presentations in those aged 80 years and over.

We suggest the following potential reviewers Judy Lowthian, Oran Rigby or Kate Curtis. There email addresses are as follows: Judy.Lowthian@monash.edu droranrigby@gmail.com kate.curtis@sydney.edu.au

We hope you find the work of value to your journal and your readership.

Regards,

Michael Dinh

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AGE-RELATED TRENDS IN INJURY AND INJURY SEVERITY PRESENTING TO EMERGENCY DEPARTMENTS IN NEW SOUTH WALES AUSTRALIA: IMPLICATIONS FOR MAJOR INJURY SURVEILLANCE AND TRAUMA SYSTEMS

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WORD COUNT – 2396, 29 references, 2 tables and 4 figures

CONFLICTS OF INTEREST STATEMENT

Rebecca Ivers was supported by a Career Development Fellowship from the National Health and Medical Research Council of Australia during the preparation of this manuscript.

The remaining authors have no conflicts of interest.

TO: 27th May 2016

Editor-in-Chief

Injury

RE: Manuscript revision_Ms. No. JINJ-D-16-00785

Dear Editor,

Thank you for the time and effort spent reviewing our work and the opportunity to re-submit a revised version to your Journal.

We have addressed all comments and the changes are highlighted in yellow. These changes are tabled below.

1. Data linkage method has been clarified – only the ED dataset was used and linkage performed to obtain individual patient level data across all facilities in NSW
2. Regional and rural population proportions have been added to the manuscript
3. The rural location of most “other hospitals” has been addressed in discussion
4. Data source and calendar year dates have been added to Figure legends and table headings
5. The two grammatical corrections suggested by reviewer two have been included

Once again, many thanks for your efforts and the opportunity to present our work

Regards,

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FIGURE LEGENDS

Figure 1 – Age specific rates of injury presentations to Emergency Departments in New South Wales for calendar years 2010 and 2014. Data source: NSW Emergency Department Data Collection Registry

Figures 2 – Yearly trends in age specific rates of critical injury presentations to Emergency Departments in New South Wales for calendar years 2010 and 2014. Data source: NSW Emergency Department Data Collection Registry

Figures 3 – Yearly trends in age specific rates of serious injury presentations to Emergency Departments in New South Wales for calendar years 2010 and 2014. Data source: NSW Emergency Department Data Collection Registry

Figures 4 – Yearly trends in age specific rates of minor injury presentations to Emergency Departments in New South Wales for calendar years 2010 and 2014. Data source: NSW Emergency Department Data Collection Registry

Table 1– Annual change in critical injury presentation rates (per 1000 population) to NSW Emergency Departments by age group in calendar years 2010-14. Data source: NSW Emergency Department Data Collection Registry

Age bracket	2010	2014	Annual % change	Incidence Rate Ratio	95% CI
0-9 years	0.38	0.51	6.36%	1.10	1.04, 1.17
10-19 years	0.48	0.61	5.03%	1.08	1.04, 1.12
20-39years	0.39	0.60	9.04%	1.14	1.09, 1.20
40-59years	0.33	0.62	13.55%	1.20	1.14, 1.25
60-79years	0.42	0.74	12.18%	1.17	1.13, 1.21
80 years and over	0.72	1.50	15.83%	1.19	1.15, 1.24

Table
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Table 2 - Comparison of characteristics in critically injured patients (n=19873) by facility type. Data source: NSW Emergency Department Data Collection Registry

	Major Trauma centre (9) N=8108	Tertiary non major trauma centre (17) N=4373	Other non trauma hospital (89) N=7392	P value
Age (%)				<0.001
0-9yrs	686 (8.5)	472 (10.8)	1089 (14.7)	
10-19yrs	869 (10.7)	471 (10.8)	1183 (16.0)	
20-39yrs	2316 (28.6)	1124 (25.7)	1923 (26.0)	
40-59yrs	1899 (23.4)	1019 (23.3)	1571 (21.3)	
60-79yrs	1539 (19.0)	865 (19.8)	1096 (14.8)	
80+yrs	798 (9.8)	421 (9.6)	528 (7.1)	
Male (%)	5744 (70.8)	3095 (70.8)	5283 (71.5)	0.62
Ambulance (%)	7295 (90.0)	3181 (72.7)	3191 (43.2)	<0.001
NSW Metropolitan Hospital Presentations (%)	8108 (100)	2661 (60.5)	2100 (28.4)	<0.001
Mode of separation (%)				<0.001
Critical Care ward	4735 (57.4)	1537 (35.2)	831 (11.2)	
Operating theatre	2038 (25.1)	521 (11.9)	302 (4.1)	
Died in ED	285 (3.5)	150 (3.4)	121 (1.6)	<0.001
Transferred	1050 (13.0)	2165 (49.5)	6138 (83.0)	
Injury type (%)				
Head injury	1844 (22.7)	1083 (24.8)	1211 (16.4)	
Chest injury	500 (6.2)	246 (5.6)	388 (5.3)	
Abdominal/pelvic	302 (3.7)	187 (4.3)	200 (2.7)	
Upper limb	667 (8.2)	491 (11.2)	1418 (19.2)	
Lower limb	595 (7.3)	283 (6.5)	766 (10.4)	
Spine/vertebral column	206 (2.5)	147 (3.4)	216 (2.9)	
Penetrating injury	119 (1.5)	82 (1.9)	195 (2.6)	<0.001

IRRs reflect the change per annum estimated using data from all 5 years, and the annual % change is based on a comparison between the first and last year's only.

Figure

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Figure 1

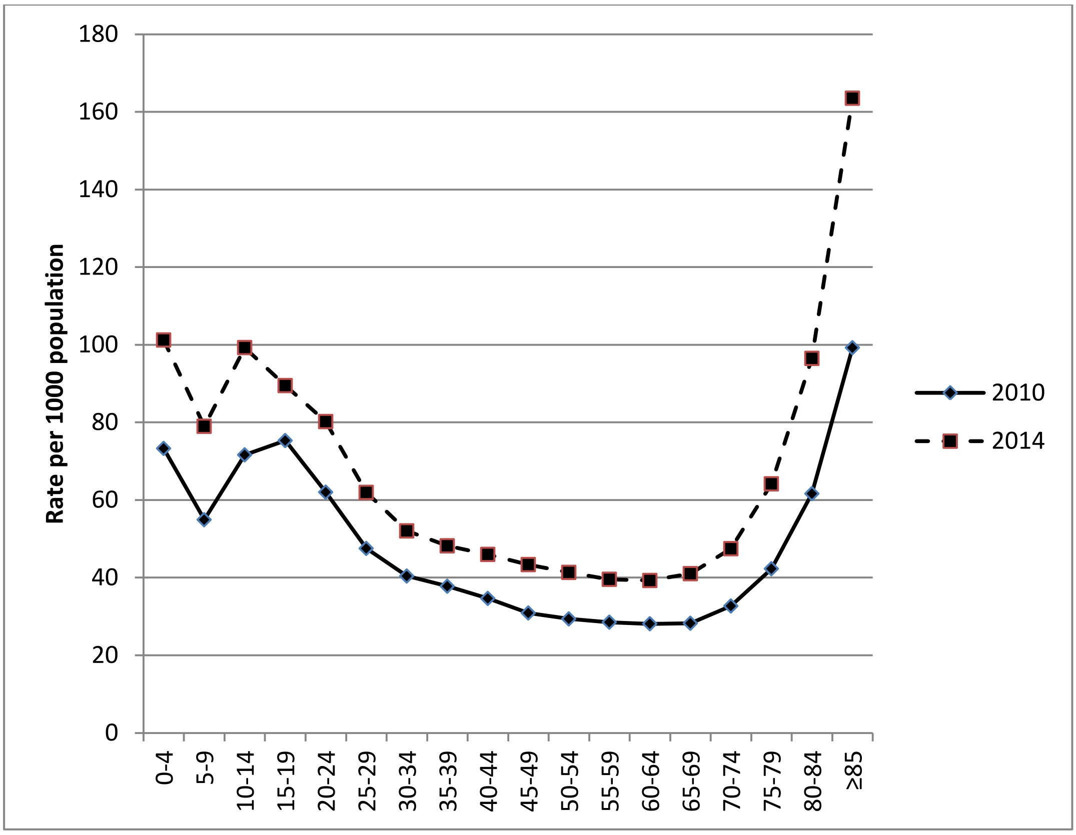

Figure 2
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Figure 2

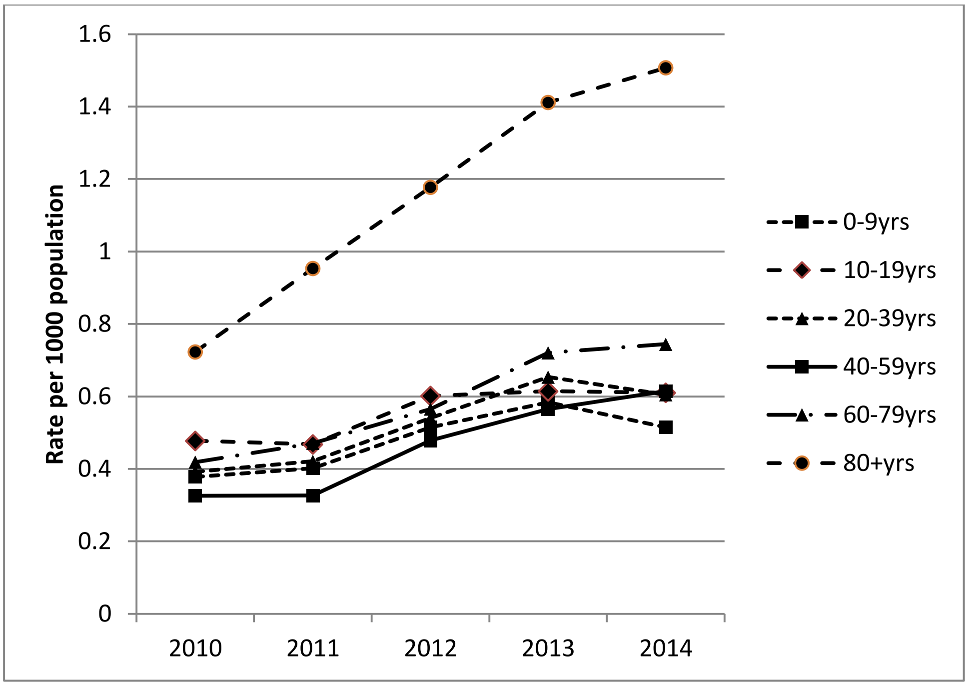

Figure 3

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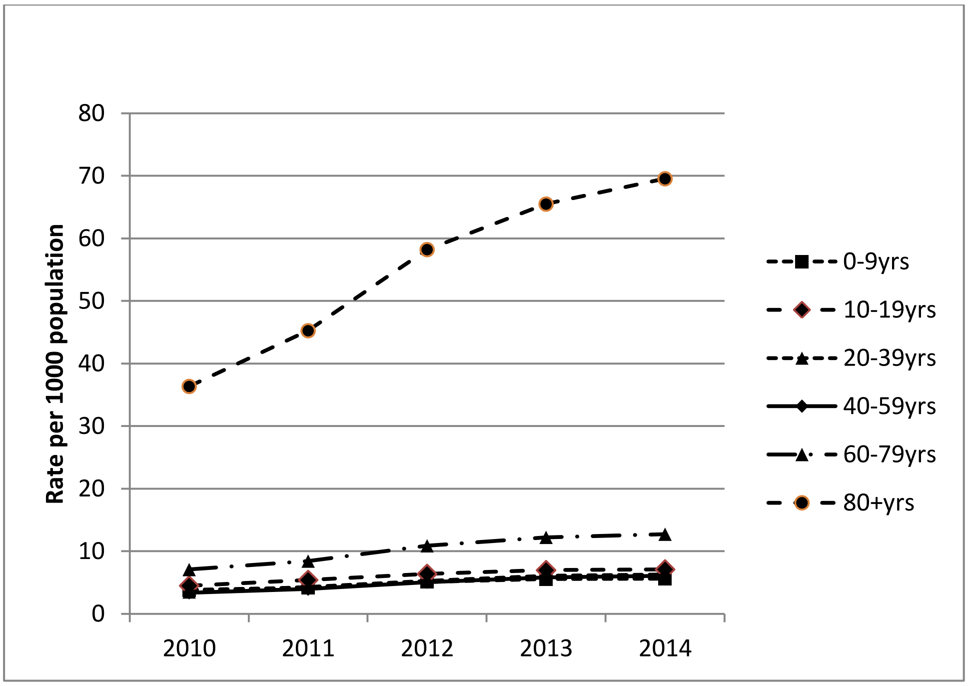

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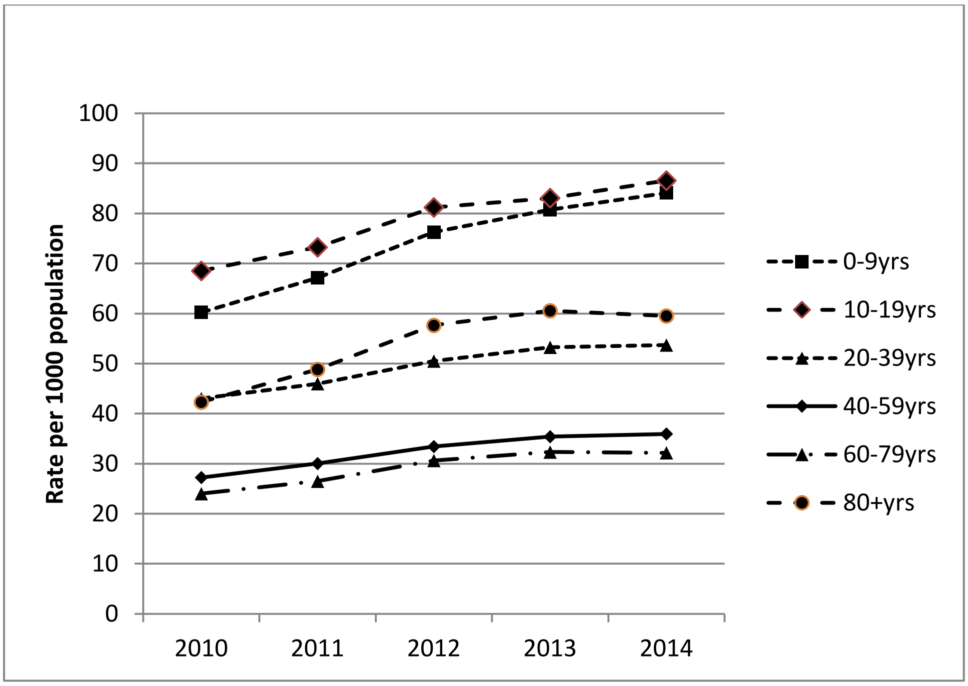
Figure 4



AGE-RELATED TRENDS IN INJURY AND INJURY SEVERITY PRESENTING TO EMERGENCY DEPARTMENTS IN NEW SOUTH WALES AUSTRALIA: IMPLICATIONS FOR MAJOR INJURY SURVEILLANCE AND TRAUMA SYSTEMS

KEYWORDS - Injury, Emergency Department, Trauma

WORD COUNT – 2396, 29 references, 2 tables and 4 figures

ABSTRACT

Objectives: To describe population based trends and clinical characteristics of injury related presentations to Emergency Departments (EDs).

Design and Setting: A retrospective, descriptive analysis of de-identified linked ED data across New South Wales, Australia over five calendar years, from 2010 to 2014.

Participants: Patients were included in this analysis if they presented to an Emergency Department and had an injury related diagnosis. Injury severity was categorised into critical (triage category 1-2 and admitted to ICU or operating theatre, or died in ED), serious (admitted as an in-patient, excluding above critical injuries) and minor injuries (discharged from ED).

Main outcome measures: The outcomes of interest were rates of injury related presentations to EDs by age groups and injury severity.

Results: A total of 2.09 million injury related ED presentations were analysed. Minor injuries comprised 85%, and 14.1% and 1% were serious and critical injuries respectively. There was a 15.8% per annum increase in the rate of critical injuries per 1000 population in those 80 years and over, with the most common diagnosis being head injuries. Around 40% of those with critical injuries presented directly to a major trauma centre.

Conclusion: Critical injuries in the elderly have risen dramatically in recent years. A minority of critical injuries present directly to major trauma centres. Trauma service provision models need revision to ensure appropriate patient care. Injury surveillance is needed to understand the external causes of injury presenting to hospital.

INTRODUCTION

Injury remains a leading cause of morbidity and mortality around the world[1] and accounts for almost one quarter of Emergency Department (ED) presentations in Australia.[2] Trauma systems have been shown to improve outcomes for severely injured patients, but monitoring and improving the effectiveness of trauma systems requires robust data collection at a population level.[3] Whilst data relating to hospital outcomes for severe trauma is routinely collected from designated trauma centres, the patients presenting to non-trauma centres are less robustly accounted for. This has the potential to affect the applicability of the age –related trends seen in trauma registries to regions, populations or non-trauma centre hospitals.[4] Use of ED presentation data, can potentially provide this information, though there are limited studies of population based injury trends using this type of data.

ED presentation databases have the advantage of capturing all injury related presentations regardless of disposition, severity of injury and hospital designation.[5] This is important given the majority of patients who present are seen and discharged from ED.[6] Compared to ED databases (unless data linkage is performed), inpatient and trauma registry data have greater detail in terms of diagnostic codes and hospital outcomes data.[7] Nevertheless, ED databases enable a broad description of epidemiological trends and clinical characteristics such as urgency, disposition and mode of arrival. These are necessary for surveillance of particular injuries such as burns, occupational injury, and geriatric trauma, and to identify gaps in a given trauma system that require additional support.[7,8] This has particular implications for current and future trauma and pre-hospital service planning in rural and remote locations. This is especially true given the current concentration of Major Trauma Services in urban environments[4], and the need for these to network with smaller hospitals serving rural and regional areas.

We sought to describe population based trends and clinical characteristics of injury related presentations to EDs, and to compare clinical characteristics of injury presentations to EDs within major trauma centres and non-trauma centres.

MATERIALS AND METHODS

Design and setting – This was a retrospective, descriptive analysis of de-identified linked Emergency presentations across NSW over five calendar years, 2010 to 2014. New South Wales is the most populous state in Australia, with seven designated adult major trauma centres, two specialist major paediatric trauma centres and ten regional trauma centres.4 Around 72% of the population live in metropolitan areas of New South Wales with a further 20% residing in inner regional and 8% in remote or outer regional locations and these have not changed significantly during the study period[9].

Data sources

The Emergency Department Data Collection (EDDC) registry contains routinely collected administrative and clinical data for patient level presentations across all public hospital emergency departments in NSW. Probabilistic linkage was performed by the NSW Centre for Health Record Linkage (CHereL) to obtain patient level data across all sites and avoid double counting of patient encounters due to transfers between facilities[6]. Data obtained for this analysis included arrival mode, patient registration, type of visit, triage category, mode of separation, and the ED diagnosis entered made at the time of discharge. Estimated Residential Populations (ERP) by age and sex, per year, were obtained from the Australian Bureau of Statistics[9] and used to calculate age specific population rates.

Patient population – Patients were included in this analysis if they presented to an Emergency Department and had an injury related diagnosis recorded by clinicians as their primary ED diagnosis based on Systematized Nomenclature of Medicine Clinical Terms (SNOMED-CT) concept identifiers, or Australian clinical versions 9 or 10 of the International Classification of Diseases (ICD). Patients transferred from other health facilities were excluded to avoid double counting of presentations and patients who were dead on arrival were also excluded. A number of small rural Emergency Departments (n=35) were excluded due to incomplete data submission in 2010-11 to minimise bias in reported trends. Patient presentation was used as the unit of analysis to measure workload on ED, not individual level risk.

Data variable definitions - A full list of data definitions and data collection methods for the EDDC were available at http://www0.health.nsw.gov.au/policies/pd/2009/PD2009_071.html. Emergency Department levels were defined using current NSW Ministry of Health role delineations for public hospitals, which take into account the complexity of clinical activity and the staffing and support services at a given hospital[10]. These ranged from Level 6 being tertiary referral centres to Level 1 small rural multi-purpose centres. For the purposes of this study, hospitals were divided into Major Trauma Services (n=9, Adult and/or Paediatric centres), Tertiary non major trauma centres (n=17, Level 5 or 6 Emergency Departments, including all regional trauma centres but excluding major trauma centres), and other non trauma centres (n=89, all other facilities). Major and regional trauma centres were identified using the current NSW State Trauma Plan[4]. Presenting problems entered at the time of patient arrival to ED by triage nurses, and ED diagnoses entered by treating physicians were categorised into broad diagnostic groups by the investigating team based on the relevant coding system (ICD10AM codes S00.0-S99.9, T00.0-35.7, T79.2-79.9, V01.00-Y05.99, Y20.00-34.99 mapped to equivalent codes in ICD9CM and SNOMED terms). Examples of these injuries included but were not limited to burns, lacerations, sprains, strains, fractures, falls and trauma. If an ED diagnoses was not recorded, the investigating team used the presenting problem to classify injury. Only 0.7% of the dataset had an ED diagnosis or presenting problem that could not be classified.

The Australasian Triage Scale (ATS) was used to define urgency with category one indicating immediately life-threatening, category two indicating imminently life-threatening, category three indicating potentially life threatening, category four and five indicating potentially serious and less urgent presentations respectively.[11] Patient details including age, gender and Indigenous status were recorded at the time of patient registration in the ED.

Injury severities were categorised, based on ED measures of urgency and mode of separation, into critical (presenting with triage category one or two and admitted directly from ED to the Intensive Care Unit or operating theatre, or died in ED), serious (admitted as an in-patient, excluding above critical injuries) and minor injuries (discharged from ED). These categories were used instead of diagnostic codes or injury severity because we wanted to investigate workload and complexity in ED rather than post hoc measures of injury severity.

Outcomes

Outcomes of interest were rates of injury related presentations to Emergency Departments by age group and injury severity. These were reported by calendar years.

Statistical analysis

Annual rates of change for each age group were calculated using the compound interest formula $[(P_1/P_0)^{1/n})-1]*100$ where P_1 is the final rate P_0 the initial rate and n denoting the number of years[12]. Chi square tests were used to compare characteristics between trauma centre designations. Population data for the Sydney Statistical Division was obtained from the Australian Bureau of Statistics[9] Categorical variables were compared using Chi squared tests. Incidence rate ratios (IRR) for age specific trends in presentation counts were estimated on aggregated data using generalised negative binomial regression using population as the exposure variable. Statistical analyses were performed using SAS Enterprise Guide version 4.3 (SAS Institute Cary NC). Age specific rates per 1000 population were calculated and plotted using Microsoft Excel.

Ethics

Approval for access to de-identified data was obtained through the NSW Population & Health Services Research Ethics Committee and the Aboriginal Health and Medical Research Council Ethics Committee**.**

RESULTS

Patient population

There were 10.8 million ED presentations identified during the study period of which 2.09 million (19.4%) had an injury related primary ED diagnosis. The next most common ED diagnosis categories were abdominal/gastrointestinal (12.5%) and respiratory (8.9%) and cardiovascular (8.0%).

1.5 million individuals accounted for the 2.09 million presentations to EDs with injuries meaning that 74.8% of patients presented only once during the study period. Of all injury presentations, males comprised 59.1% of the study population, 22.1% were transported by ambulance and the overall in-patient admission rate was 16%. With respect to injury severity, 1777851 (85.0%) were minor, 294479 (14.1%) were serious and 19873 (1.0%) were critical injuries. The rate of critical injuries increased overall by 10.4%, serious injuries by 12.6% and minor injuries by 5.3% per annum.

Figure one shows age (5 yearly intervals) specific rates of injury related presentations to ED between 2010 and 2014 demonstrating peaks in paediatric age groups and those older than 80 years of age. There was an apparent increase in presentation rates in all age groups which was most pronounced in those over 85 years of age.

Figures two to four show the change in presentation rates by broad age group and injury severity, and demonstrates the rapid increase in critical and severe injuries in those over 80 years of age (and relatively stable trend in other age groups). In particular for critical injuries, annual rates of increase are shown in table one.

Critical injuries and trauma centre designation

Table two compares the patient characteristics with respect to trauma designation of the presenting hospital for the subset of critically injured patients (n=19,873). Of these, 40.8% presented to a major trauma centre, 22% to a tertiary non-major trauma centre and 37.2% presented to other hospitals. Patients presenting to major trauma centres were older and more likely to be transported by ambulance compared to those at other non-trauma centres. Around half of all critical injuries presenting to tertiary non-major trauma centres and 83% of those presenting to other hospitals were transferred to another facility. There were higher proportions of head and abdominal/pelvic injuries in those presenting to tertiary non-major trauma centres compared to major trauma centres (4.3% versus 3.7%). Of the 1747 patients aged 80 years or over who had critical injuries, 6.0% were referred by a nursing home or other aged care facility, and the three most common injury diagnosis types were head injury (30%), lower limb (10.8%), and chest injury (8.3%).

DISCUSSION

This is the first Australian study to identify the trends and characteristics of all injuries presenting to ED at a state wide level. Although increases in injury presentations were in general observed across all age groups from 2010-2014, the study highlighted a dramatic increase in the rate of critical and serious injuries in patients 80 years and over. The findings from this study has important implications for future trauma service planning and broader injury management and prevention policies.[13]

Studies have pointed to the increase in proportion and cost of geriatric trauma.[14] Trauma service plans and injury management strategies in general need to take into account these demographic changes. It is clear that older trauma patients have increased mortality and morbidity for a given injury severity.[15]The management of the elderly population tends to be more complex owing to medical comorbidities, polypharmacy (including anticoagulation), social circumstances, and the need for longer recovery times and rehabilitation after injury. Given the management complexity of injured elderly patients, surgically-based trauma services may need to include greater emphasis on medical management. These may evolve from separate trauma-geriatric models of care, similar to ortho-geriatric services, to specific geriatric injury networks and referral pathways.[16] Other issues that need addressing include post discharge community support, sub-acute care and palliation for patients with advanced care directives or in whom aggressive trauma management is deemed futile.

Furthermore, the large number of presentations of patients categorised as ‘critically injured’ to non-major regional trauma centres requires further investigation. Currently data for severe injuries (Injury Severity Score >12), is collected only from Major Trauma Centres.[17] However, the data presented here suggests that the burden of initial treatment is shared across other hospitals, and including data from these hospitals increases the estimate of the numbers of severely injured patients in New South Wales. A substantial proportion of critically injured patients presented to “other hospitals” and the majority of these were rural hospitals with limited direct access to the metropolitan major trauma centres. The number of Major Trauma cases reported by NSW Major Trauma Centres in 2013 was 3,411 (Injury Severity Score >12)[17] whereas the number of critical injuries in the same year identified in our study was 43.5% higher (4881 cases). The distribution of critical injuries across all types of facilities in this study highlights the need for a coordinated system of care and data collection across the state. Ambulance transport accounts for 43% of critically injured patients presenting to non-trauma/non-tertiary centres. These are largely smaller rural centres where access to ambulance and retrieval services may be lacking and where improved pre-hospital services may lead to direct transportation to more appropriate regional and major trauma centres. An effective retrieval and inter-hospital transport service has been shown to reduce mortality in severely injured patients.[18]

The definition of critical injury used in trauma registries is based on post admission injury severity scores.[4] The definition used in our study is based on death or the allocation of a high urgency triage category together with the need for transfer, operating theatre or intensive care unit admission. This reflects those requiring urgent or complex specialist interventions in the ED context. Moreover the 3% mortality of these critically injured patients of observed in this study is consistent with that reported in a study of patients transported on ambulance major trauma transport protocols.[19] further study linking this data to major trauma data of the same patient group will help establish the validity of this definition of injury severity with respect to the anatomic injury scores used in trauma registries.

Given the large proportion of injury presentations treated and discharged (85%) from ED, and the lack of detailed external cause of injury data recorded in ED systems, there is a significant gap in our knowledge about the true burden of injury in Australia.[20] Injury surveillance systems which include external cause data are essential to injury prevention through the identification of the numbers, causes, mechanisms, and risk factors for injury,[21,22] and routine emergency department patient databases in Australia do not facilitate injury surveillance. There are some advances in mining the presenting problem text which is commonly recorded in ED data which may allow for further interrogation of ED data, however for more systematic injury surveillance purposes the inclusion of a designated data field to capture external cause of injury coded data in ED systems is needed.[23,24]

Besides the definition of critical and severe injuries, another limitation to the study is the use of injury based ED diagnoses. These are likely to underestimate the true rate of injuries because symptom-based diagnoses such as ankle pain or chest wall pain were specifically excluded from the injury category used. As the analysis was performed on presentations and not patients we did not account for any representations of the same individuals. These are particularly relevant in the elderly who are more likely to return with, for example, recurrent falls. However, on a clinical and health service level, the assessment and treatment of injured patients, in general, is not impacted by the number of times they represent.[25]

This study highlights the need to urgently address trauma models of care, trauma service provision, and referral networks to ensure quality service provision for the growing demand on injury care. ED-based injury surveillance, which includes external cause data and short text-based injury descriptions are also needed to better understand the causes of injuries to allow the targeting of prevention activities to reduce the high rate and growth in geriatric trauma.

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A trauma quality improvement programme associated with improved patient outcomes: 21 years of experience at an Australian Major Trauma Centre

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ABSTRACT

Introduction: Quality improvement programmes are an important part of care delivery in trauma centres. The objective was to describe the effect of a comprehensive quality improvement programme on long term patient outcome trends at a low volume major trauma centre in Australia.
Methods: All patients aged 15 years and over with major trauma (Injury Severity Score > 15) admitted to a single inner city major trauma centre between 1992 and 2012 were studied. The outcomes of interest were in-hospital mortality and transfer to rehabilitation. Time series analysis using integer valued autoregressive Poisson models was used to determine the reduction in adjusted monthly count data associated with the intervention period (2007–2012). Risk adjusted odds ratios for mortality over three yearly intervals was also obtained using multivariable logistic regression. Crude and risk adjusted mortality was compared before and after the implementation period.
Results: 3856 patients were analysed. Crude in-hospital mortality fell from 16% to 10% after implementation ($p < 0.001$). The intervention period was associated with a 25% decrease in monthly mortality counts. Risk adjusted mortality remained stable from 1992 to 2006 and did not fall until the intervention period. Crude and risk adjusted transfer to in-patient rehabilitation after major trauma also declined during the intervention period.
Conclusion: In this low volume major trauma centre, the implementation of a comprehensive quality improvement programme was associated with a reduction in crude and risk adjusted mortality and risk adjusted discharge to rehabilitation in severely injured patients.

Introduction

Substantial evidence currently exists supporting the relationship between adequately resourced trauma centres operating within regionalised trauma systems and improved mortality in severely injured patients [1,2]. A study in Victoria Australia, demonstrated a decrease in risk adjusted patient mortality over five years after the implementation of a state-wide trauma system [3]. A pre and post implementation study across four years in the Netherlands also demonstrated a 16% reduction in risk adjusted in-patient mortality [4]. There are few studies that examine long term trends in mortality. An inclusive state-wide trauma system in Delaware was associated with a 25% absolute reduction in crude mortality for severely injured patients (Injury Severity Score > 24) over ten years [5]. Investigators at the R Adams Cowley Shock trauma centre also studied trends in mortality over ten years between 1997 and 2008 and found a small decrease in mortality in patients with an Injury Severity Score between 17 and 24 [6].

Whilst the emphasis in trauma care evaluation has focused on systems across regions, few studies have investigated the impact of quality improvement processes within individual trauma centres over the long term. Variations in outcomes have been demonstrated across many trauma centres of similar capabilities and may reflect differing approaches to quality improvement [7]. A study by Sarkar et al. [8] from Michigan USA evaluated the effect of a

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comprehensive performance improvement programme and demonstrated a 12% reduction in trauma mortality (ISS > 24) over five years at a Level 1 trauma centre. A recent study across four countries identified differences in quality improvement processes used in low volume compared to high volume trauma centres (greater than 240 patients per year with an ISS > 15) [9]. Low patient volume trauma centres were associated with higher use of benchmarks associated with triage, patient flow and effectiveness of care. Higher patient volume centres reported higher use of benchmarks related to medical errors and adverse events.

It is unclear whether such quality improvement programmes can result in improved patient outcomes that are achievable and sustainable in the Australian context. A State-wide trauma system in New South Wales, Australia with a population of over 7 million people, was established in 1992 [10]. There are currently seven designated adult Major Trauma Centres, six of whom are located in metropolitan Sydney. As a consequence of this concentration of trauma centres, most of these would be considered low to medium volume trauma centres under current international standards [9].

The objective of this study was to describe the effect of a comprehensive quality improvement programme on long term patient outcome trends at one of these Major Trauma Centres. We sought to analyse longitudinal trends using two statistical methods – logistic regression of aggregated data and multivariable time series analyses. Information gained may help confirm the importance, effectiveness and sustainability of rigorous quality assurance processes at trauma centres, particularly those within trauma systems where lower patient volume trauma centres predominate.

Materials and methods

Design – single centre trauma registry study over 21 years

Setting – the study was conducted at an inner City Major Trauma Centre in Sydney, Australia's largest city. There are currently around 200 major trauma presentations (ISS > 15) per year. Although a State-wide trauma system was implemented in 1992, there was only one part time trauma director prior to 2006 at this institution, and no structured trauma education programme or quality improvement processes. In 2007 a comprehensive trauma quality improvement programme was initiated after the appointment of three trauma Co-Directors – an Emergency Physician, Colorectal Surgeon and Orthopaedic Surgeon. The programme consisted of implementation of a tiered trauma team activation protocol, mandatory notification criteria for Trauma Surgeon and Emergency Physician on-call, a structured trauma education and case review programme, massive transfusion protocol and implementation of a number of quality benchmarks consistent with those described in previous studies (9). These quality benchmarks, or key performance indicators formed the basis of trauma case reviews conducted by trauma clinical nurse consultants on every admitted trauma patient and reported at monthly committee meetings. In 2009 a hospital wide 'Code Crimson' for expedited surgical management of haemorrhage in trauma was initiated.

All trauma patients requiring in-patient rehabilitation are transferred to external rehabilitation facilities, including brain injury units outside this institution and there have been no major changes to referral patterns over the past 20 years.

A single trauma data manager has prospectively collected data on all trauma admissions to this institution into the trauma registry since 1991.

Study population – all adult patients (age ≥ 15 years) with major trauma (ISS > 15) presenting to this hospital between January 1992 and December 2012 were included. Cases were excluded if information on patient outcomes were missing. All deaths in the emergency department were included, excluding those who had absent vital signs on arrival to hospital and did not receive treatment in the emergency department.

Data collected – data collected for this study included demographics (age, sex), mechanism of injury, mode of arrival, vital signs on arrival to the emergency department, injuries and injury severity score and patient outcomes. Injuries and injured body regions were classified using the Abbreviated Injury Scale [11] (AIS) 1990 and 1998 versions prior to 2009 and 2005 version thereafter. Severe head injuries were defined as any head injury with an AIS severity score of three or more. Period of presentation was divided into three yearly intervals to enable long term risk adjusted trends to be presented.

Outcomes – the primary outcome was in-hospital mortality. All deaths in the Emergency Department were included. The secondary outcome was transfer to in-patient rehabilitation facilities in patients surviving to hospital discharge, as a proxy marker of functional impairment requiring ongoing medical care.

Statistical analysis

A univariate analysis to compare before and after periods with respect to patient characteristics and outcomes was performed. Two statistical methods were used to analyse the effect of the intervention period on major trauma mortality. Firstly the effects of the intervention period on monthly in-hospital mortality counts was analysed using integer valued autoregressive Poisson models, adjusting for age (age ≥ 65 years, seasonality (warmer months from October to March)) and any underlying linear trend. The intervention period was considered a binary variable (before and after). The distribution of monthly deaths was assumed to follow a Poisson distribution. This modelling technique has been shown to be superior to other time series methods such as autoregressive integrated moving average models where counts are relatively low [12]. To graphically represent the trend in adjusted monthly mortality counts, we plotted predicted monthly mortality values based on the above autoregressive Poisson model, and fitted segmented linear trend lines for the values in the before and after periods respectively.

Secondly, risk adjusted mortality and rehabilitation trends (in survivors to hospital discharge) were determined using multivariable logistic regression with data aggregated into three-year intervals, compared to reference years (2004–2006) just prior to the intervention period, and a priori defined variables based on a previous studies [3,13] and known to vary across time at this institution [14]. Three year aggregated data intervals were used due to the relatively small number of major traumas at this institution and the need to adjust mortality using a large number of covariates. Binary variables were severe head injury (Head Abbreviated Injury Scale score ≥ 3), transfer from another health facility, hypotension (systolic blood pressure < 90 mmHg on arrival to emergency department) and Intensive Care Unit admission. Age, ISS and mechanism of injury were categorised into clinically relevant categories as shown in Table 1. All analyses were conducted using SAS 9.3 (SAS Institute, Cary, NC) except for time series analysis which was performed using STATA 10.1 (Statacorp, College Station, TX).

Results

A total of 3873 cases were identified of which 17 had missing outcome data, leaving 3856 cases analysed. The mean age was 48 years (SD 22) and 74% were male. The number of major trauma admissions each year has increased slowly from around 150 patients per year prior to year 2000 to around 200 patients per year

Table 1
Comparison of baseline characteristics before (1992–2006) and after (2006–2012) implementation of quality improvement programme IQR = interquartile range, transfer = arrival from another health facility, rehabilitation = transfer to in-patient rehabilitation services (excluding deaths), AIS = Abbreviated Injury Scale, SBP = systolic blood pressure. Penetrating mechanism includes gun injuries, stabbings and self inflicted penetrating injuries.

	1992–2006 N = 2605	2007–2012 N = 1251	p value
Age (median, IQR)	42 (27.64)	51 (32.72)	<0.001
Age 14–24 yrs (%)	508 (20)	171 (14)	
Age 25–44 yrs (%)	871 (33)	347 (28)	
Age 45–64 yrs (%)	583 (22)	313 (25)	
Age 65–84 yrs (%)	540 (21)	326 (26)	
Age >84 yrs (%)	103 (4)	94 (8)	<0.001
Male (%)	1953 (75)	914 (73)	0.20
Interhospital transfer (%)	739 (28)	238(19)	0.001
ICU (%)	1728 (66)	603 (48)	0.001
SBP < 90 mmHg (%)	206 (8)	87 (7)	0.29
ISS			
16–24	1361 (52)	758 (61)	
25–49	1101 (42)	455 (36)	
>50	143 (5)	38 (3)	<0.001
Mechanism			<0.001
Falls	889 (34)	596 (48)	
Road trauma	1004 (39)	380 (30)	
Blunt assault	282(11)	109(9)	
Penetrating	196 (8)	62 (5)	
Other	234 (9)	104 (8)	
Head (AIS ≥ 3) (%)	1819 (70)	857 (69)	0.40
Spine/Vertebral column (AIS ≥ 3) (%)	174(7)	131(10)	0.01
Chest (AIS ≥ 3) (%)	818 (31)	405 (32)	0.54
Abdomen (AIS ≥ 3) (%)	398 (15)	129 (10)	<0.001
Upper limb (%)	642 (25)	353 (28)	0.02
Lower limb (%)	674 (26)	335 (27)	0.55
In-hospital mortality (%)	420 (16)	128 (10)	<0.001
Inpatient rehabilitation (%)	820 (38)	318 (28)	<0.001
Length of stay (days, median IQR)	9(4.19)	8 (4.19)	0.32

after 2001.The overall mortality was 14% and of the survivors to hospital discharge, 34% were transferred to rehabilitation facilities.

A comparison of baseline characteristics before (1992–2006) and after (2007–2012) the implementation of the quality improvement programme is shown in Table 1. Patients in the "after" group were associated with older age, increased proportion of falls and severe spinal or vertebral column injuries, similar proportion of severe head injuries and reduced admissions to ICU. Crude in-hospital mortality decreased from 16% to 10% ($p < 0.001$) as did transfers to in-patient rehabilitation (38% versus 28%, $p < 0.001$).

Time series analyses (monthly counts)

After adjusting for age and seasonality, the coefficient value of the intervention period (2007–2012) was −0.29 (95%CI −5.64, −0.01) which equates to a 25% reduction in monthly death counts associated with the onset of the intervention period after adjusting for underlying trends (Table 2). Fig. 1 graphically presents the trend in adjusted log monthly mortality counts and demonstrates the decrease in mortality since 2007.

Risk adjusted outcomes (three year intervals)

Risk adjusted mortality (Table 3) remained steady compared to the reference period (2004–2006) and fell to 0.72 (95%CI 0.41, 0.94, $p = 0.025$) in 2007–2009 and decreased further thereafter. The adjusted odds ratio for a simple before and after analysis using the same adjustment variables in Table 3 revealed a 40% reduction in risk adjusted mortality associated with the post intervention period (2007–2012) (OR 0.59, 0.46, 0.76, $p < 0.001$) compared to the pre-intervention period (1992–2006). Odds ratios for transfer to in-patient rehabilitation also fell significantly between 2007 and 2009 (OR 0.69 95%CI 0.53, 0.91, $p = 0.01$) and 2010–2012 (OR 0.51 95%CI 0.39, 0.69, $p < 0.001$) after adjusting for age, severe head injury, lower limb injury and ISS.

Discussion

The present study was undertaken to describe long term trends in patient outcomes and the impact of quality improvement processes implemented since 2007 at an Australian major trauma centre. Using a time series analysis approach, the period after 2006 was associated with a 25% reduction in mortality after major trauma after adjusting for underlying trends. Using risk adjustment techniques, the period after 2006 was associated with a statistically significant reduction in risk adjusted mortality. This improvement was paralleled by a decrease in risk adjusted transfer for in-patient rehabilitation after major trauma.

The reduction in crude mortality to around 10% over the past six years compares favourably to the overall major trauma mortality in New South Wales which has remained around 13–14% throughout the last decade, as well as the most recent mortality data available from Victoria [15–17] and mortality for patients with an ISS > 15 of around 12% in the quality improvement study by Sarkar et al. [8].

Few studies have explored the association between the presence of trauma quality improvement systems and reduced risk adjusted mortality [13]. A cross sectional survey of 59 trauma hospitals in Quebec Canada found that the presence of a quality improvement programme was the strongest predictor of survival after risk adjustment [17]. A recent study by Wong et al. from a larger trauma service in NSW demonstrated a 3% reduction over 10 years in crude mortality since the introduction of a specialist trauma service with similar clinical care protocols [15]. This study was unable to adjust mortality for abnormal physiology, intensive care use or underlying time trends.

The quality improvement programme instituted in 2007 included many elements of the minimum criteria for trauma centre verification but also interventions that are not explicitly defined by the American College of Surgeons Committee on Trauma [2,18]. These elements included a tiered trauma team activation criteria, code crimson, and specific quality benchmarks

Table 2
Integer valued autoregressive (AR) Poisson model for monthly deaths from major trauma, SE = standard error, AR(1) = autoregressive term with 1 month lag. Root mean square error = 0.44, intervention period = binary variable (2007–2012).

Variable	Coefficient	SE	95%CI	p value
Constant	−1.55	0.43	−2.39, −0.70	<0.001
Log_e(monthly total major trauma)	0.89	0.17	0.56, 1.22	<0.001
Monthly trend	−0.020	0.00088	−0.0037, −0.0002	0.029
Seasonality (October–March)	0.043	0.083	−0.20, 0.12	0.61
Age (≥65 yrs)	0.043	0.021	0.0038, 0.084	0.048
Intervention period (2007–2012)	−0.29	0.14	−0.56, −0.01	0.042
AR(1)	0.028	0.06	−0.091, 0.15	0.64

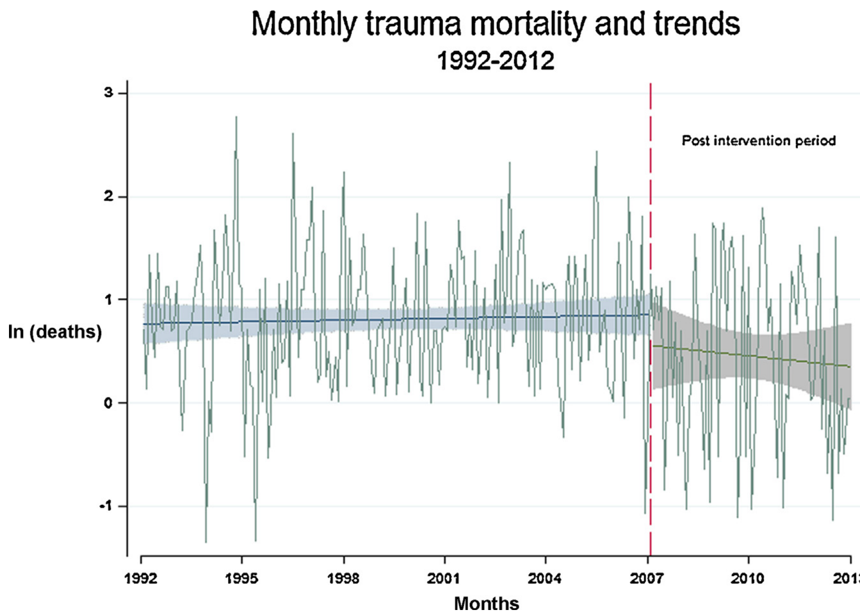

Fig. 1. Adjusted monthly mortality ($\log_e$[death]) counts using autoregressive (AR1) Poisson modelling. Segmented linear regression lines before and after intervention (2007) with 95% confidence intervals (shaded).

such as time to radiology, definitive care and tertiary surveys. The findings of the present study are timely given the recent establishment of the Australian Quality Improvement Programme (AustQIP), a collaboration of 26 major trauma centres including this institution [19]. The aim of AustQIP is to enable an integrated and coordinated approach to quality systems and patient safety initiatives across all trauma centres in Australia.

The changes described here were achieved at a low volume trauma centre which has not employed a full time trauma surgeon since 1998. The trauma surgeon on call roster at this institution was staffed by surgeons from multiple subspecialties. Although some studies suggest that full time trauma surgeons are associated with better outcomes for severely injured patients [20], other studies point out that the relationship is more complex, and that characteristics of the trauma system at any given hospital may play a more important role in determining outcomes [21].

Table 3
Risk adjusted odds ratios (OR) for mortality including all variables used for adjustment, AIS = Abbreviated Injury Scale, SBP = systolic blood pressure, ISS = Injury Severity Score, penetrating mechanism includes gun injuries, stabbings and self inflicted penetrating injuries.

	OR	95%CI	*p*
1992–1994	0.88	0.58, 1.32	0.54
1995–1997	1.04	0.69, 1.57	0.85
1998–2000	0.98	0.65, 1.47	0.92
2001–2003	0.96	0.65, 1.43	0.86
2004–2006	[reference]	–	–
2007–2009	0.62	0.41, 0.94	0.025
2010–2012	0.57	0.37, 0.57	0.01
Age 14–24	[reference]	–	–
25–44	0.86	0.60, 1.25	0.42
45–64	1.46	0.96, 2.07	0.07
65–84	2.51	1.71, 3.57	$<$0.001
$>$85 yrs	4.86	2.89, 8.28	$<$0.001
SBP $<$ 90 mmHg	7.64	5.37, 10.85	$<$0.001
ISS 15–24	[reference]	–	–
ISS 25–49	13.44	9.76, 18.48	$<$0.001
ISS $>$ 50	73.62	44.25, 119.20	$<$0.001
Mechanism			
Other	[reference]	–	–
Blunt assault	0.57	0.33,0.97	0.04
Road trauma	1.31	0.89, 1.92	0.17
Fall	0.83	0.55, 1.25	0.36
Penetrating	2.01	1.12, 3.62	0.02
Head (AIS $\geq$ 3)	2.52	1.84, 3.46	$<$0.001
Transfer	0.69	0.54, 0.89	0.004
ICU	0.94	0.92, 0.96	$<$0.001

The strengths of the present study include the length of time studied, the use of time series analysis to adjust for underlying long term trends, and the use of risk adjustment for in-hospital mortality and discharge to rehabilitation. This is the first study in Australia to report on long term trends in trauma mortality using both fully risk adjusted models and multivariable time series analyses which strengthens the robustness of the findings. The advantages of reporting long term trends and time series analyses include the ability to demonstrate sustained improvements in patient outcomes and adjusting for existing trends before the introduction of system changes. It therefore reduces the risk of error in attributing observed changes to an intervention rather than an underlying trend or random variation over short periods of time. Few studies involving major trauma have reported long term trends in rehabilitation use, even though rehabilitation is a key component of the trauma system and may be considered a marker of severe ongoing disability that may be mitigated by improved early management for trauma [22].

There were a number of acknowledged limitations to the study. Monthly mortality counts were low and this may affect the robustness of our conclusions. The present study has accounted for this by using appropriate time series modelling. Several important changes over the past decade may have partly explained the observed trends that were not accounted for in the study. These include improved care of patients in Intensive Care Units, through better ventilation strategies and management of sepsis and multi-organ failure [23,24], increased staffing with Emergency Physicians, damage control surgery and improved access to diagnostic and interventional Radiology. In addition several changes to road traffic laws in New South Wales over the past 20 years, such as reduced urban speed limits and drink driving laws have resulted in reduced road fatalities [25], resulting in more patients with severe injuries surviving to hospital admission and ultimately discharge. Therefore the observed trends in this series may not be a result of the intervention but may simply be the result of gradual improvements in medical care and injury prevention measures undertaken over the past two decades. The study has attempted to account for many of these changes by adjusting for mechanism of injury, intensive care admission, and patient age as well as any underlying trends through time series modelling. Given the long time period analysed, the authors also analysed a subgroup of patients from 2001 to 2012 and obtained similar results for crude and adjusted mortality before and after the intervention period (OR 0.58 95%CI 0.43, 0.78, $p < 0.001$).

Although performance indicators were regularly audited, we have not presented trends in protocol compliance here, given the number and complexity of indicators involved. Therefore it is not clear from this investigation whether the observed improved outcomes were a result of reducing variability in care or an improvement in the timeliness of care. We were not able to compare our performance with contemporaneous trends across New South Wales as data after 2009 were not available at time of writing. Finally this was a single centre study, and some of the quality improvement processes described here and the improved outcomes associated with them may not be transferable to other institutions.

In conclusion, in this single centre study, the introduction of a comprehensive quality improvement programme was associated with a modest reduction in long term crude and risk adjusted mortality and discharge to rehabilitation in severely injured patients. It remains unclear which component of the programme was most important in reducing mortality. Maintaining and improving on observed trends describe here will be one of the main challenges going forward, particularly in the context of an ageing population, and the anticipated revisions to the trauma system in New South Wales.

Conflict of interest statement

None declared.

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Author contributions

MMD – study design data analyses and manuscript preparation. KJB – data analyses and manuscript review. CMB – study design and manuscript preparation. JP – study design and manuscript preparation. BJG – data analyses and manuscript review. RI – manuscript review and study supervisor.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.injury.2013.11.005.

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Incremental cost-effectiveness of trauma service improvements for road trauma casualties: experience of an Australian major trauma centre

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Abstract

Objective. The aim of the present study was to estimate the cost-effectiveness of trauma service funding enhancements at an inner city major trauma centre.

Methods. The present study was a cost-effectiveness analysis using retrospective trauma registry data of all major trauma patients (injury severity score >15) presenting after road trauma between 2001 and 2012. The primary outcome was cost per life year gained associated with the intervention period (2007–12) compared with the pre-intervention period (2001–06). Incremental costs were represented by all trauma-related funding enhancements undertaken between 2007 and 2010. Risk adjustment for years of life lost was conducted using zero-inflated negative binomial regression modelling. All costs were expressed in 2012 Australian dollar values.

Results. In all, 876 patients were identified during the study period. The incremental cost of trauma enhancements between 2007 and 2012 totalled $7.91 million, of which $2.86 million (36%) was attributable to road trauma patients. After adjustment for important covariates, the odds of in-hospital mortality reduced by around half (adjusted odds ratio (OR) 0.48; 95% confidence interval (CI) 0.27, 0.82; $P = 0.01$). The incremental cost-effectiveness ratio was A$7600 per life year gained (95% CI A$5524, $19 333).

Conclusion. Trauma service funding enhancements that enabled a quality improvement program at a single major trauma centre were found to be cost-effective based on current international and Australian standards.

What is known about this topic? Trauma quality improvement programs have been implemented across most designated trauma hospitals in an effort to improve hospital care processes and outcomes for injured patients. These involve a combination of education and training, the use of audit and key performance indicators.
What does this paper add? A trauma quality improvement program initiated at an Australian Major Trauma Centre was found to be cost-effective over 12 years with respect to years of life saved in road trauma patients.
What are the implications for practitioners? The results suggest that adequate resourcing of trauma centres to enable quality improvement programs may be a cost-effective measure to reduce in-hospital mortality following road trauma.

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Introduction

Trauma quality improvement programs involve a coordinated, systematic and sustained endeavour to monitor and improve aspects of trauma care delivery.[1–3] By identifying and addressing deficiencies in care in hospitals, the primary goal of the trauma quality improvement program is to improve patient outcomes after injury. Several studies have documented improvements in process of care and patient mortality associated with the implementation of hospital-based trauma quality improvement programs, most often in conjunction with the implementation of regionalised trauma systems.[4–10]

Although the effectiveness of trauma systems of care and quality improvement programs has been studied extensively, there are few studies examining the cost-effectiveness of such interventions. There is a growing need to demonstrate value for money associated with trauma system improvements, given the current climate of rising healthcare costs and the perception that trauma care is expensive.[11] Cost-effectiveness analysis provides a metric that informs policy makers about which programs and interventions yield the highest health benefit for a given amount of health spending. [12]

The National Study on Costs and Outcomes of Trauma in the US measured healthcare-related costs and found the cost-effectiveness of trauma centre care compared with non-trauma centre care to be around US$36 000 per quality-adjusted life year (QALY) gained.[11] DiRusso *et al*.[6] demonstrated a significant reduction in mortality after changes to their trauma program undertaken as a result of a trauma centre verification process. Estimated cost savings of around US$4000 per patient were demonstrated associated with reduced length of stay. No published studies to date have examined the cost-effectiveness of trauma quality improvement programs in Australia.

New South Wales (NSW) is the most populous state in Australia, and a state-wide trauma system was implemented in 1992.[13] Over the past decade, a series of funding enhancements was appropriated to major trauma centres in NSW to ensure adequate medical and nursing expertise in trauma and to facilitate hospital-based trauma quality improvement programs.[13] We sought to estimate the cost-effectiveness of these trauma enhancements at one of these major trauma centres, Royal Prince Alfred Hospital in Sydney. Such information facilitates decisions regarding funding and resource allocation in the context of injury management.

Methods

Design

The present study was a retrospective pre-post intervention cost-effectiveness analysis at the hospital provider level, conducted at a single major trauma centre in NSW, Australia.

Setting and trauma service intervention

The trauma centre is located in the inner city area in Sydney and treats approximately 3000 injury-related admissions per annum, of which approximately 220 are classified as major trauma (injury severity score (ISS) >15, calculated using the 2005 version of the Abbreviated Injury Scale[14]). The hospital trauma registry has routinely collected complete clinical information on all trauma-related in-patient admissions since 1992. Prior to 2007, the trauma service consisted of a part-time (0.5 full-time equivalent (FTE)) trauma director, a full time trauma clinical nurse consultant and a data manager. Between 2007 and 2010, a series of funding enhancements resulted in the employment of an additional 0.5 FTE trauma director, primarily to provide clinical governance and leadership, an additional FTE trauma clinical nurse consultant and an FTE trauma case manager. This enabled several improvements to the trauma service to occur that were not present before 2007, namely:

(1) Collection of clinical data on all trauma patients, including those who were discharged directly from the emergency department, where previously only data on in-patient admissions were collected.
(2) Establishment of a validated hospital-wide tiered trauma team activation protocol.[15] Trauma team protocols also included an assessment tool and escalation policy for unstable patients and a 'Code Crimson' integrated policy for patients requiring urgent haemorrhage control.[16] This involved the simultaneous mobilisation of both operating theatre staff and massive transfusion protocols. These protocols were not present before 2007.
(3) Trauma key performance indicators, including time to imaging studies and definitive care benchmarks that were used as audit filters by trauma nurses who reviewed all patients requiring trauma team activation;
(4) Weekly patient review meetings where audit filters were reviewed for each trauma patient requiring trauma team activation regardless of admission status.
(5) Two-monthly trauma team training courses using high-fidelity simulation facilities instituted in 2009 where important protocols and teamwork were taught and practiced.

Patient population

Patient data from the hospital trauma registry were included for adult (aged 15 years or over) major trauma patients (ISS >15) presenting between January 2001 and December 2012 who had been admitted after a road trauma mechanism of injury. Road trauma was defined if the injured person was the occupant of a motor vehicle (car, truck, bus, motorbike), pedestrian or cyclist. The ISSs were calculated using the 2005 version of the Abbreviated Injury Scale,[14] with scores before 2005 recalculated using the same version to ensure consistency.

Primary study measure

The incremental cost-effectiveness ratio was estimated from a hospital provider perspective using cost per life year gained associated with the intervention compared with the pre-intervention period (see below).

Costs

Incremental costs were represented by all trauma-related funding enhancements undertaken between 2007 and 2010. These included salaries and wages for additional staffing as outlined above, staffing for an additional intensive care unit (ICU) bed commissioned in 2010 for trauma and staffing for an additional emergency department resuscitation bed. The cost of a Trauma Orthopaedics Fellow employed in 2010 was also included. Total cost of the trauma centre improvements was allocated to road trauma patients based on their percentage share of all trauma patients (36%). Unit salary costs were obtained directly from the hospital. Therefore, these costs comprised only additional staffing costs and cost savings were not considered in the study.

Effectiveness

Patient administrative data for trauma centre patients were obtained from the hospital. Records included information relating to admission date, length of stay, demographic characteristics, body region of injury, nature of injury, mechanism of injury, injury severity and survival. Effectiveness was measured by comparing years of life lost (YLL) for each death for the pre-intervention period (2001–06) and the post-intervention period (2007–12), with YLL calculated using 2009–11 Australian life tables.[17] The outcome measure of life years gained was the difference in YLL between the pre- and post-intervention periods.

Base year and discounting

The base year for the analysis was 2012. Costs and outcomes were discounted at an annual rate of 5% as recommended in guidelines for preparing submissions to the Pharmaceutical Benefits Advisory Committee.[18]

Statistical analysis

Univariate comparison of demographic and injury-related characteristics and hospital episode of care for the pre- and post-intervention periods was performed using descriptive statistics. Zero-inflated negative binomial regression was used for modelling YLL to account for excess zeros in the outcome variable and over-dispersion.[19] Risk adjustment modelling variables were based on those used by the American College of Surgeons Trauma Quality Improvement Program, such as age, injury severity, ICU admission, severe head injury and the presence of hypotension (systolic blood pressure (SBP) <90 mmHg), but did not include comorbidities.[3] All analyses were conducted using SAS 9.3 (SAS Institute, Cary, NC, USA). Model discrimination and calibration were reported using the area under the receiver operating characteristic (ROC) curve and the Hosmer–Lemeshow test statistic, respectively.

Sensitivity analysis

To test whether the results of the base case analysis were dependent on the discount rate and the estimate of the reduction in YLL derived in the present study, a sensitivity analysis was conducted by varying these two parameters over a range considered plausible. For YLL, the 95% confidence intervals (CIs) of the odds for dying in the post- compared with pre-intervention period were used to calculate 95% CIs of the number of life years gained at each discount rate. The annual discount rate was varied from 0% to 8%.

Ethics

Data retrieval was approved by the Ethics Review Committee of the Sydney Local Health District.

Results

In all, 876 patients were identified during the study period. The median age was 39 years (interquartile range (IQR) 25–58 years) and 74% were male. Motor vehicle (car) incidents accounted for 34% of the study population, motorcyclists for 16%, pedestrians for 33% and cyclists for 6%. Other mechanisms (bus or other motorised vehicle) accounted for the remaining 11% of the population. There were 460 patients in the pre-intervention group and 416 patients in the post-intervention group. Demographic and clinical characteristics of the study groups are compared in Table 1. The most notable differences were a significant increase in the proportion of cyclists and motorcyclists in the post-intervention period, as well as fewer ICU admissions.

Costs

The incremental cost of trauma enhancements between 2007 and 2012 totalled A$7.91 million, of which A$2.85 million (36%) was attributable to road trauma patients.

Effectiveness

Unadjusted in-hospital mortality decreased from 16% in the pre-intervention group to 10% in the post-intervention group, representing a 38% relative reduction (odds ratio (OR) 0.58; 95% CI 0.39, 0.89; $P = 0.01$). After adjustment for age, sex, mechanism of injury, hypotension (SBP <90 mmHg), severe head injury, ICU admission and inter-hospital transfer, the finding remained significant (adjusted OR 0.48; 95% CI 0.27, 0.82; $P = 0.01$; Table 2).

There was a significant reduction in mean YLL per patient in the post-intervention period compared with pre-intervention period (2.4 years per patient (95% CI 1.8, 2.9) vs 1.5 years per patient (95%CI 1.1, 2.0); $P = 0.003$). Using the post-intervention sample size as the reference, there were 374 years of life gained in the post-intervention group compared with pre-intervention group assuming a 5% discount rate per annum.

Incremental cost-effectiveness ratio

The incremental cost-effectiveness ratio was A$7613 (95% CI A$5524, A$19 333) per life year gained (Table 3).

Sensitivity analysis

Under the different discount rates adopted, the incremental cost of implementing the trauma improvement program varied from A$2.272 million for an annual discount rate of 8% to A$3.630 million with no discounting (Table 3). Incremental effectiveness varied from 250 life years gained (95% CI 99, 346) at an 8% discount rate to 915 life years gained (95% CI 362, 1266) with no discounting. Thus, the incremental cost-effectiveness for the best case scenario was A$3967 (95% CI A$2867, A$10 027) per life year gained and for the worst case scenario was A$9090 (95% CI A$6600, A$23 068) per life year gained.

Discussion

The present study reports on a quality improvement program, similar to the original framework (structure, process and outcome) described by Donabedian over 40 years ago.[20] Structural changes included additional staffing and increased resuscitation bay and ICU capacity. Process changes were exemplified by trauma team protocols, trauma team training and key performance indicators. Outcomes reported in the present study were in-hospital mortality and years of life saved. The findings

Table 1. Comparison of demographic and injury characteristics in severely injured road trauma patient in the pre- and post-intervention groups

Unless indicated otherwise, data are given as *n* (%). IQR, interquartile range; SBP, systolic blood pressure; ISS, injury severity score; AIS, Abbreviated Injury Scale; LOS, length of stay; ICU, intensive care unit

	Pre-intervention group (2001–06; $n = 460$)	Post-intervention group (2007–12; $n = 416$)	*P*-value
Demographics			
Median (IQR) age (years)	38 (24, 57)	41 (27, 59)	0.09
No. men (%)	328 (71%)	324 (78%)	0.03
Injury mechanism			
Motor vehicle (car)	180 (39%)	122 (29%)	
Motorcyclist	56 (12%)	87 (21%)	
Pedestrian	161 (35%)	128 (31%)	
Cyclist	12 (3%)	42 (10%)	
Other	51 (11%)	37 (9%)	<0.001
Clinical characteristics			
SBP <90 (%)	41 (9%)	39 (9%)	0.81
Median (IQR) ISS	23 (17, 30)	21 (17, 29)	0.03
Severe injury (AIS ≥3) by body region			
Head	305 (66%)	247 (59%)	0.03
Face	75 (16%)	87 (21%)	0.09
Neck	4 (1%)	2 (0.5%)	0.49
Chest	192 (42%)	195 (47%)	0.13
Abdomen	75 (16%)	65(16%)	0.78
Spine	47 (10%)	43 (10%)	0.95
Upper limb	20 (4%)	6(1%)	0.01
Lower limb	122 (27%)	116 (28%)	0.65
Hospital episode of care characteristics			
ICU admission	326 (71%)	223 (54%)	<0.001
Transfer	135 (30%)	128 (31%)	0.65
Median (IQR) LOS (days)	11 (4, 22)	9 (4, 24)	0.83
Discharge to rehabilitation	115 (25)	97 (23)	0.56
Median (IQR) cost weight per patient	4.4 (1.9, 13.3)	4.1 (1.9,12.7)	0.69

Table 2. Adjusted odds ratios (OR) for in-hospital mortality

Area under the receiver operating characteristic (ROC) curve = 0.87 (95% confidence interval (CI) 0.83, 0.90); Hosmer–Lemeshow test statistic 9.67, d.f. = 8, $P = 0.28$. ICU, intensive care unit admission; SBP, systolic blood pressure; Transfer, transported by retrieval services from another hospital; ISS, injury severity score

	OR	95% CI	*P*-value
Post intervention period (2007–12)	0.48	0.27, 0.82	0.01
Age (years)	1.03	1.01, 1.04	<0.001
Sex (male vs female)	0.81	0.46, 1.44	0.48
ISS	1.09	1.07, 1.11	<0.001
Mechanism (vs other)			
Motor vehicle (car)	0.37	0.16, 0.86	0.02
Motorcyclist	0.43	0.15, 1.19	0.10
Pedestrian	0.34	0.15, 0.79	0.01
Cyclist	0.67	0.17, 2.65	0.57
SBP <90 mmHg	7.27	3.62, 14.60	<0.001
Severe head injury (AIS ≥3)	3.33	1.72, 6.46	<0.001
Transfer	0.86	0.46, 1.62	0.65
ICU admission	0.72	0.40, 1.23	0.28

of the present study demonstrate a 50% reduction in adjusted odds of mortality associated with trauma service enhancements and a quality improvement program initiated in 2007. The mortality reduction remained significant after adjustment for differences in age and ISS between the two study groups. The

Table 3. Incremental costs, effectiveness and cost-effectiveness of trauma service improvements (expressed in 2012 A$)

CI, confidence interval

Discount rate	Intervention cost (A$)	Life years gained (95% CI)	Cost (A$) per life year gained (95% CI)
0%	3 629 606	915 (362, 1266)	3967 (2867–10 027)
3%	3 306 755	499 (197, 690)	6627 (4792–16 786)
5%	2 847 115	374 (148, 518)	7613 (5496–19 261)
8%	2 272 410	250 (99, 346)	9090 (6568–22 954)

cost-effectiveness of the trauma service enhancements was estimated to be around A$7600 for each year of life gained between the two study periods.

Several injury-prevention strategies have been evaluated with cost-effectiveness analyses using mathematical modelling and available evidence.[21] In general, primary prevention measures were found to be the most cost-effective, but were dependent on the prevalence of particular modes of transport and context.[22] The findings give additional impetus to trauma quality improvement programs, and are timely given the recent establishment of the Australian Trauma Registry and Australian Trauma Quality Improvement Program.[23] The findings of the present study confirm that trauma quality improvement programs can be a cost-effective measure to reduce in-hospital mortality following road trauma.

There are several limitations to the present study. First, the study was conducted at a trauma centre with relatively low trauma patient volumes compared with international standards,[9] so specific interventions and improvement programs reported here may not be as relevant or replicated in larger trauma centres. Second, we focused only on a hospital-based intervention and did not seek to estimate the ongoing direct and indirect costs incurred after discharge from hospital or the benefits of survivors in relation to employment and productivity. Furthermore, we did not measure deaths after hospital discharge with increased mortality reported in those sustaining severe trauma several years after the event.[24]

Third, mortality trends across the two time periods may simply reflect gradual reductions in major trauma mortality because of clinical improvements over the past two decades. However, a recent study at Royal Prince Alfred Hospital demonstrated that risk-adjusted mortality for all major trauma patients only began to decline after 2007.[15] It is likely that this mortality reduction has resulted from a combination of improved staff training, institution of trauma team activation and massive transfusion protocols that were all part of the quality improvement process. For instance, the rate of missed injuries (significant injuries not identified during trauma team assessment) between 2003 and 2006, when audits were initiated, was 13/782 (1.7% of all major trauma patients), compared with 4/1244 (0.3% of all major trauma patients) during the post-intervention period. It remains unclear which specific quality improvement initiative was primarily responsible for improved patient outcomes. However, it is clear that these initiatives require staffing and resources, which would not have been possible without the funding enhancements described above. Fourth, we did not include other important contributors of major trauma, such as falls and other non-road trauma-related mechanisms. Road trauma was used in the present analysis because of defined funding mechanisms in this state that fund road injury costs and rehabilitation, and to allow direct comparisons with cost-effectiveness of other road safety initiatives.[21,22]

Finally the usefulness of cost-effectiveness analyses is context specific and depends on factors such as the ability and willingness of any given society to pay for the intervention. Therefore, monetary thresholds for cost-effectiveness ratios should be interpreted with caution. The most widely publicised threshold as a rule of thumb is the US$50 000 per QALY gained.[25] Expressed in 1997 values, these were arbitrarily based on the costs of renal dialysis at the time. More recently, the National Institute of Heath and Clinical Excellence (NICE) defined a threshold value of £20 000–£30 000 per QALY gained as cost-effective.[26] The World Health Organization standardises cost-effectiveness across regions by using three times the gross domestic product per capita as the threshold value.[27] Based on this definition, a threshold of between A$60 000 to $90 000 per QALY gained appears to be reasonable in the Australian context and is consistent with the thresholds described for pharmaceutical interventions in Australia of A$40 000 to A$70 000 per life year gained.[28] Based on these thresholds, the incremental cost-effectiveness ratios of the trauma service improvements would be considered cost-effective even in the worst case scenario using an annual discount factor of 8%.

In conclusion, a program of trauma service enhancements that enabled a quality improvement program between 2007 and 2010 was associated with a significant reduction in severe road trauma mortality at an Australian Major Trauma Centre. The funding enhancements were found to be cost-effective based on current international and Australian standards and confirm that trauma quality improvement programs can be a cost-effective measure to reduce in-hospital mortality from road trauma.

Competing interests

None declared.

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Health status and return to work in trauma patients at 3 and 6 months post-discharge: an Australian major trauma centre study

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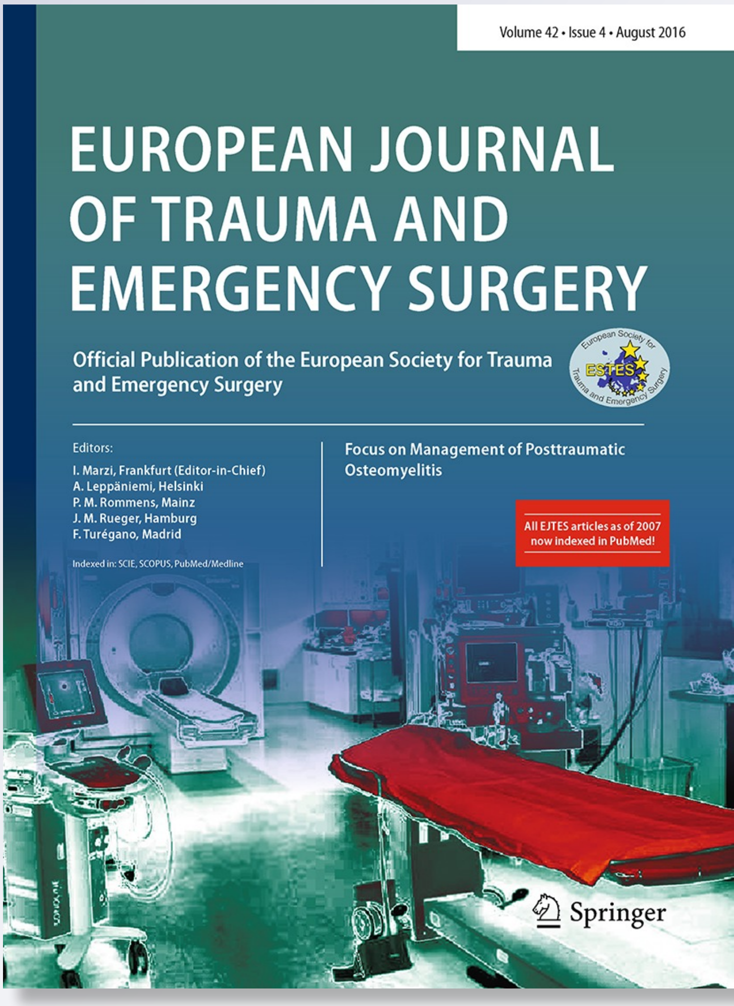

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ORIGINAL ARTICLE

Health status and return to work in trauma patients at 3 and 6 months post-discharge: an Australian major trauma centre study

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Abstract
Introduction The aim of this study was to describe post-discharge outcomes, and determine predictors of 3 and 6 months health status outcomes in a population of trauma patients at an inner city major trauma centre.
Methods This was a prospective cohort study of adult trauma patients admitted to this hospital with 3 and 6 months post-discharge outcomes assessment. Outcome measures were the Physical Component Scores (PCS) and Mental Component Scores (MCS) of the Short Form 12, EQ-5D, and return to work (in any capacity) if working prior to injury. Repeated measures mixed models and generalised estimating equation models were used to determine predictors of outcomes at 3 and 6 months.
Results One hundred and seventy-nine patients were followed up. Patients with lower limb injuries reported lower mean PCS scores between 3 and 6 months (coefficient −4.21, 95 % CI −7.58, −0.85) than those without lower limb injuries. Patients involved in pedestrian incidents or assaults and those with pre-existing mental health diagnoses reported lower mean MCS scores. In adjusted models upper limb injuries were associated with reduced odds of return to work at 3 and 6 months (OR 0.20, 95 % CI 0.07, 0.57) compared to those without upper limb injuries.
Discussion Predictors of poorer physical health status were lower limb injuries and predictors of mental health were related to the mechanism of injury and past mental health. Increasing injury severity score and upper limb injuries were the only predictors of reduced return to work. The results provide insights into the feasibility of routine post-discharge follow-up at a trauma service level.

Keywords Trauma · Health outcome · Follow-up

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Introduction

With improved survival after major trauma over the past few decades, the emphasis in trauma outcomes research has shifted from in-hospital mortality to investigating factors that influence long-term health outcomes after injury [1–3]. Some of these factors include age [4], severity of injury [5, 6], level of education [6], brain injury [7–9], ongoing pain [10] and compensable status [11]. Regardless of the factors involved or specific measures used, there is substantial evidence that seriously injured patients experience ongoing disability months to years after injury [12].

Determining long-term outcomes of trauma patients is important to establish and benchmark the effectiveness of systems of care for the injured, and inform policy and research priorities. Some studies have investigated these outcomes on a population or regional level [13, 14]. There are also a number of studies that describe the post injury health outcomes from a single trauma centre perspective [15–17]. Single centre studies have been limited by the use of differing or non-validated health related quality of life (HRQoL) measures [16], varying follow-up strategies and difficulties related to follow-up [17].

Given the cost and burden of injury to society and the importance of routinely monitoring post-discharge health status, it was felt that an investigation using validated HRQoL measures consistent with population level studies [13] would help establish the feasibility of routine patient follow-up at a trauma service level. It would also enable the identification of factors amendable to future post-discharge clinical interventions and the value of further outcomes analysis. The aim was therefore to describe post-discharge outcomes at a trauma service level, and determine predictors of 3 and 6 months health status outcomes in a population of trauma patients at an inner city major trauma centre.

Materials and methods

Setting

The study was conducted at a single inner city Major Trauma Centre in Sydney Australia, with around 600 in-patient trauma team admissions per annum.

Design

This was a prospective cohort study with recruitment of eligible patients during in-hospital admission and 3 and 6 months post-discharge outcomes assessment.

Inclusion criteria

Eligible participants were trauma patients who were aged 16 years and over, admitted between July 2012 and July 2013. Trauma patients were defined as those who were transported from the scene by NSW Ambulance Service, underwent a trauma team assessment in the emergency department, subsequently admitted as an in-patient to the hospital and had a tertiary survey performed by the trauma service within 24–48 h of admission.

Exclusion criteria

Patients were excluded if they were transferred from another hospital as the study was designed to inform local follow-up procedures, represented with injury following enrolment into the study, persistent vegetative state or expectant death within 72 h of arrival (to minimise distress to relatives), required high level care prior to injury, unable to consent due to pre-existing cognitive impairments or mental health illness, could not speak adequate English and did not have access to an interpreter at home, or presented after penetrating trauma or self inflicted injury. These exclusions were based on the need to obtain informed consent prior to enrolment, and expected difficulties associated with poor follow-up of patients of non-English speaking backgrounds without access to a translator, and those with penetrating and self-inflected injuries at this institution.

Outcomes

Outcome measures were the Physical Component Scores (PCS) and Mental Component Scores (MCS) of the Short Form 12 (SF-12) Version 2 (acute), consistent with previous population-based studies [13]. Higher PCS and MCS scores denote improved health status. Return to work and EQ-5D items were also assessed.

Enrolment procedure

Eligible patients were identified during routine post admission ward rounds by the trauma team. Study procedures were explained by trained Trauma Clinical Nurse Consultants and written informed consent was obtained from the patient, or assent from the next of kin, prior to discharge from hospital. Follow-up telephone calls were conducted by a single Trauma Case Manager. These calls occurred at 3 and 6 months post hospital discharge. Two weeks prior to telephone contact, a reminder letter and study brochure were mailed out to participants addresses, re-explaining the study and the purpose of the interview. If the patient or the next of kin could not be contacted after three attempts over 2 weeks at both 3 and 6 months follow-up calls, the patient was considered lost to follow-up. Deaths after discharge were checked using district-wide electronic medical records and the NSW Birth Deaths and Marriage Registry.

Data collection

The following data points, based on the Victorian State Trauma Registry [13], were collected:

- Baseline—age, marital status, residential status, education level attained, pre-injury employment status.
- Three and 6 months follow-up—Short Form 12 (SF-12) Version 2 (acute), EQ-5D, and return to work (in any capacity) if working prior to injury.

Prior to study commencement, a 1 day field trip to the Victorian State Trauma Registry was undertaken by the trauma service as part of training in follow-up procedures and assessment tools. Proprietary scoring software for SF-12 Version 2 acute recall (4 weeks) (QualityMetric, Lincoln, RI, USA) and Australian weights and norms [18] were used to calculate PCS and MCS. Data were linked by medical record number and presentation date to this hospital's trauma data registry and electronic medical records to obtain clinical and injury details (mechanism of injury, in-patient length of stay, injury severity score (ISS), intensive care unit admission, transfer to rehabilitation, financial classification (compensable under NSW Motor Accidents Authority) and comorbidities. Patients were classified as having any medical comorbidity or previous mental health diagnosis based on 10th revision of the International Classification of Diseases Australian modification (ICD-10-AM) coding. Highest education level attained was categorised into university or post graduate level versus secondary or primary school level. A medical student entered baseline and follow-up data into a separate database which then required linkage (by medical record number and date of presentation) to data in the trauma registry and proprietary SF-12 scoring software.

Statistical analysis

Descriptive statistics were used to present baseline demographics and 3 and 6 months outcomes. Means were expressed with standard deviations (SD) and medians with interquartile ranges (IQR). Repeated measures mixed models were used to determine predictors of PCS and MCS modelled as continuous variables at 3 and 6 months. Covariates used in multivariable models were derived from previous literature [1–13]. To determine the change over time in these outcomes, interaction terms between interview number (1, 3 months; 2, 6 months follow-up interviews) and covariates of interest were included in all models. Generalised estimating equations with a log link function were used to compare repeated binary measures such as EQ-5D domains (no problem versus any reported problem), and return to work in the subset of patients who were less than 65 years of age and working prior to admission to hospital. Analyses were conducted using STATA version 13.1 (STATACORP College Station, TX, USA).

Results

Screening and enrolment population

Over a 1 year recruitment period, 349 patients were assessed for eligibility by the trauma team. Of these 222 eligible patients (64 %) were enrolled in the study. When comparing these to the 126 patients who were assessed for eligibility but were subsequently excluded prior to enrolment, there was no difference in mean age of 46 (19) years versus 47 (21) years ($p = 0.77$), median (IQR) ISS [8 (IQR 4–17) versus 9 (5–17) $p = 0.13$], proportion of males (78 versus 74 %, $p = 0.40$). There was a significant difference in median (IQR) LOS in the patients who were followed up compared to those who were excluded or declined [4 (2–8) versus 7 (3–15) days, $p = 0.009$].

Comparison of patients studied and those lost to follow-up

Of the 222 patients enrolled, nine patients withdrew consent after enrolment and 34 patients were lost to follow-up leaving 179 patients available for analysis with an overall follow-up rate of 80 %. Table 1 describes the baseline characteristics of recruited patients who were lost to follow-up or withdrew consent after enrolment ($n = 43$), and the study group ($n = 179$). There were no significant differences between participants and non-participants (lost to follow-up or withdrew consent) with respect to age, gender, mechanism of injury ISS, need for intensive care admission or rehabilitation (Table 1).

Outcomes of study population

For the 179 patients studied, the mean (SD) age was 46.2 (20.0) years and 139 (78 %) patients were male. The median (IQR) ISS was 9 (4–17) with an ISS >15 in 33 % of the study group. The most common mechanisms of injury were falls (32 %) and motor vehicle crashes (30 %), followed by pedestrians (15 %). Three deaths were recorded—one patient prior to discharge, one within 3 months and one within 6 months of discharge.

Health status outcomes are summarised in Table 2. Mean follow-up MCS scores increased between 3 and 6 months but did not reach statistical significance. At 3 months 36 % of respondents indicated some problem with usual activities, 37 % reported anxiety or depression with 22 % reporting psychological problems affecting relationships.

After adjusting for covariates, the presence of any lower limb injury was associated with a reduction in mean PCS of 4.21 points (coefficient −4.21 95 % CI −7.58, −0.85) compared to those without lower limb injury. The presence of abdominal injury or head injuries was associated with an

Table 1 Comparison of baseline and injury characteristics of patients who were followed up and those who were lost to follow-up or withdrew consent (non-participants)

	Participants ($n = 179$)	Non-participants ($n = 43$)	p value
Age, years, mean (SD)	46.2 (20.0)	40.6 (15.6)	0.16
Male (%)	139 (77.7)	35 (81.3)	0.59
Married/de-facto (%)	108 (60.3)	33 (76.7)	0.045
Compensable under MAA (%)	86 (48.0)	19 (44.2)	0.65
Pre-existing medical condition (%)	49 (27.4)	16 (37.2)	0.20
Pre-existing mental health diagnosis (%)	26 (14.5)	14 (32.5)	0.004
Injury Severity Score, median (IQR)	9 (4–17)	9 (5–14)	0.91
Rehabilitation (%)	24 (13.4)	6 (14.0)	0.93
Mechanism of injury (%)			0.52
Assault	15 (8.4)	7 (16.3)	
Car occupant/driver	17 (9.5)	4 (9.3)	
Motorcyclist	36 (20.1)	9 (20.9)	
Pedestrian	28 (15.6)	3 (7.0)	
Cyclist	16 (8.9)	6 (14.0)	
Fall	61 (34.1)	13 (30.2)	
Other	6 (3.4)	1 (2.3)	
Intensive care admission (%)	37 (20.7)	7 (16.3)	0.52
Body region (%)			
Head injury	92 (51.4)	23 (53.5)	0.81
Chest injury	48 (26.8)	8 (18.6)	0.27
Abdominal injury	23 (12.8)	4 (9.3)	0.52
Vertebral injury	34 (19.0)	9 (20.9)	0.77
Upper limb injury	71 (39.7)	18 (41.9)	0.79
Lower limb injury	64 (35.8)	15 (34.9)	0.92
Pelvic injury	12 (6.7)	2 (4.7)	0.62

MAA Motor Accidents Authority, *rehabilitation* transfer to external or in-patient rehabilitation units

increased PCS score between 3 and 6 months, whereas increasing ISS was associated with reduced PCS scores between 3 and 6 months (Table 3). Predictors of decreased MCS were related to mechanism of injury (assault, pedestrian), and previous history of mental health diagnosis. After adjustment, overall MCS scores decreased on average between 3 and 6 months, but was not statistically significant ($p = 0.053$).

After adjustment for age, education and compensable status, increasing ISS were associated with reduced odds of return to work (OR 0.98, 95 % CI 0.97, 0.99 $p = 0.004$). Upper limb injuries were the only injuries associated with reduced odds of return to work at 3 and 6 months compared to those who did not have upper limb injuries (OR 0.20, 95 % CI 0.07, 0.57) after adjustment. Lower limb injuries were associated with a reduced odds of return to work compared to those who did not have lower limb injuries, but did not reach statistical significance (OR 0.85 95 % CI 0.72, 1.00 $p = 0.052$).

Discussion

The present study was undertaken to describe the 3 and 6 months health outcomes of trauma patients discharged after admission to an inner city trauma centre setting. The results demonstrated that whilst unadjusted PCS improved between 3 and 6 months, after correcting for age, mechanism of injury, body regions injured, mechanism of injury and other important covariates, PCS had not improved and MCS scores may have actually decreased. A substantial proportion of patients reported at least some anxiety or depression (37 %) and relationship problems related to psychological problems (22 %) which did not reduce significantly over the duration of follow-up. Between 25 and 30 % of patients who were working previously were still not working at 3 and 6 months. These findings add important insights in the Australian context regarding the ongoing burden of injury after hospitalisation. Although only a single centre study, it also adds insights into the feasibility of routine patient follow-up of trauma patients at a trauma centre level, based on the experience reported in other studies [16, 17].

The finding that increasing age, injury severity score and lower limb injuries were associated with reduced physical health status scores contrasts with other studies. Holtslag et al. [15] used the sickness impact profile-136 in a cohort of major trauma patients (Injury Severity Score ≥ 16). Age,

Table 2 Health status outcomes at 3 and 6 months follow-up

	3 months follow-up ($n = 179$)	6 months follow-up ($n = 178$)	p value
SF-12			
Physical Component Score (mean, SD)	45.0 (10.2)	46.8 (10.3)	<0.001
Mental Component Score (mean, SD)	46.9 (11.2)	48.3 (10.2)	0.06
EQ-5D domains			
Mobility (%)			0.30
No problems	120 (67.0)	126 (70.7)	
Some problems	57 (31.8)	51 (28.7)	
Bed bound	2 (1.1)	1 (0.6)	
Self-care (%)			0.003
No problems	153 (85.5)	163 (91.6)	
Some problems	24 (13.4)	14 (7.9)	
Unable to wash/dress self	1 (0.6)	1 (0.6)	
Usual activities (%)			0.007
No problems	113 (63.1)	131 (73.4)	
Some problems	65 (36.3)	46 (25.8)	
Unable to perform	1 (0.6)	1 (0.6)	
Anxiety or depression (%)			0.88
None	112 (62.6)	113 (63.5)	
Moderately	49 (27.4)	54 (30.3)	
Extremely	18 (10.1)	11 (6.2)	
Pain/discomfort (%)			0.010
None	68 (38.0)	84 (47.2)	
Moderate	104 (58.1)	86 (48.3)	
Extreme	7 (3.9)	7 (3.9)	
Return to work (if working prior to injury $n = 125$) (%)	92 (73.6)	93 (76.0)	0.31

comorbidities, lower extremity, brain and spinal injuries were predictive of poorer outcomes in that study, whereas injury severity scores were only weakly predictive of outcomes. This may be a reflection of differing injury severities and outcome measures used, but the findings in the present and previous studies in relation to lower limb injuries were consistent with the observation that lower limb orthopaedic injuries were associated with ongoing pain and disability, months after injury [10]. Interestingly, the presence of abdominal trauma and head injury was associated with improved PCS scores between 3 and 6 months. This may be due to the exclusion of many patients with severe head injury and the low incidence of severe abdominal trauma in general, but underscores the importance of limb injury in determining longer term outcomes. The finding may also suggest that patients with abdominal injury improve over time and have less impact on health status outcomes compared to limb injuries.

The lack of improvement in PCS and MCS scores between 3 and 6 months after adjustment appears to be consistent with the findings of Gabbe et al. [19]. In a longitudinal study of major trauma patients across 24 months, improvements in PCS did not become apparent until 12 months and MCS scores did not improve until around 18 months post injury. The time frame of follow-up in the present study differs from others in that the reference point was taken at the date of hospital discharge, not the injury date. The reason for this was that one of the drivers of the present study was to design future-specific post-discharge clinical interventions at the trauma service level, with any potential post-discharge intervention taking place at a certain point after hospital discharge.

The present study differs from previous studies in a number of other aspects. This was a single centre study and was not undertaken at a regional or population level like the Victorian State Trauma Registry [13, 19, 20]. Patients were identified prospectively at the point of admission to the hospital rather than identified based on post hoc injury severity scores, length of stay or diagnoses. This contrasts with a similar single centre study from Queensland in a population of patients with medical record coded discharge diagnoses related to injury and hospital length of stay >24 h [21]. Given that most similar studies to date have focused on severe trauma (ISS >15) [20–23],

Table 3 Multivariable mixed model of SF-12 health outcomes between interview number (1, 3 months; 2, 6 months follow-up interview) and covariates

	n = 179 (%)	Physical Component Score (mean difference 95 % CI)	*p* value	Mental Component Score (mean difference 95 % CI)	*p* value
Age		−0.16 (−0.04, −0.28)	0.007	−0.12 (−0.27, 0.026)	0.10
ISS		−0.41 (−0.13, −0.69)	0.004	−0.10 (−0.46, 0.25	0.57
Gender					
Female	40 (22)	(Reference)		(Reference)	
Male	139 (78)	0.88 (−2.81, 4.57)	0.64	1.86 (−2.18, 5.90)	0.37
Education[a]					
Primary/high school/other	76 (42)	(Reference)		(Reference)	
University/postgraduate degree	103 (56)	−1.04 (−4.0, 1.90)	0.49	−2.86 (−6.11, 0.39)	0.09
Injury					
Head	92 (51)	4.32 (0.95, 7.68)	0.01	−1.5 (−5.20, 2.19)	0.42
Chest	48 (27)	1.20 (−2.20,4.59)	0.49	1.10 (−2.60, 4.81)	0.56
Abdominal	23 (13)	7.26 (2.61, 11.92)	0.002	2.30 (−2.81, 7.40)	0.38
Vertebral	34 (19)	−0.85 (−4.58, 2.87)	0.65	−0.08 (−4.16, 4.00)	0.97
Upper limb	71 (40)	−1.76 (−4.68, 1.15)	0.24	1.95 (−1.26, 5.15)	0.23
Lower limb	64 (36)	−4.21 (−7.58, −0.85)	0.01	1.90 (−1.78, 5.58)	0.31
Mechanism					
Fall	58 (32)	(Reference)		(Reference)	
Assault	14 (8)	1.78 (−3.92, 7.47)	0.54	−10.50 (−16.70, −4.27)	0.001
Car	18 (10)	−3.74 (−11.53, 4.05)	0.35	−3.96 (−12.5, 4.58)	0.36
Motorcyclist	36 (20)	−0.41 (−7.39, 6.51)	0.91	−7.10 (−14.67, 0.50)	0.07
Pedestrian	26 (15)	0.92 (−5.97, 7.81)	0.79	−10.62 (−17.82, −2.70)	0.008
Cyclist	17 (10)	5.86 (−0.17, 11.88)	0.06	−1.76 (−8.36, 4.86)	0.60
Other	10 (6)	3.95 (−3.50, 11.39)	0.30	−6.92 (−15.29, 1.46)	0.11
Comorbidities					
Any medical comorbidity	36 (20)	−2.7 (−6.38, 0.97)	0.15	1.34 (−2.67, 5.70)	0.51
Mental health diagnosis	26 (15)	1.63 (−2.31, 5.58)	0.42	−4.63 (−8.96, -0.30)	0.036
Non-compensable under MAA	93 (52)	(Reference)		(Reference)	
Compensable under MAA	86 (48)	1.85 (−3.98, 7.68)	0.53	−1.67 (−8.06, 4.71)	0.61
Change over time (6 versus 3 months)		0.04 (−5.09, 5.18)	0.99	−7.27 (−14.62, 0.08)	0.053

MAA Motor Accidents Authority

[a] Highest education level attained

this study adds new information regarding the burden of injury for the majority of admitted patients in Australian Trauma Centres that have mild to moderate injury severity. Mean PCS were 39 and MCS were 45 at 3 months follow-up in that study, which were lower than scores reported here. Patients in the present study were also recruited and followed up within the trauma service, rather than through external interviewers or self administered questionnaires mailed out. A study of over two thousand injured patients who were registered with the New Zealand no-fault injury insurance agency [24] found that around 23 % of patient reported some degree of anxiety or depression on the EQ-5D at 3 months follow-up, which was lower than the proportion (36 %) reported in the present study. Return to work in the present study was also higher than those reported in other studies [25, 26], and likely reflects differing injury mechanisms, injury severity and the specific focus on hospitalised patients in this study.

Another important finding relates to mental health. Impairments in mental health after trauma are well described in the literature and may be related to pain, financial or interpersonal stress [26–29]. Harris et al. [28] determined that the presence of an unsettled compensation claim was significantly associated with both poorer mental and physical health in a cross sectional study of major trauma patients 1–5 years post injury. This may be one reason why assault related injuries in particular were associated with lower MCS scores in this study.

Given that mental health domains do not appear to improve significantly, and perhaps deteriorate between 3 and 6 months in this study population, it would appear that any post-discharge clinical intervention aimed at improving long-term health outcomes will need to address these issues. Such interventions may include telephone counselling and referral to mental health clinicians for more detailed assessment and treatment [27]. Further analysis is underway to determine which baseline and injury factors are associated with poorer physical and mental health after 12 months post-discharge, and will inform the design and inclusion criteria for any clinical intervention at this institution.

The study has several limitations, being a relatively small single centre study. Excluding non-English speaking patients who did not have access to a family member who could interpret over the telephone was necessary given to design of this study, but may have introduced bias if such groups were associated with poorer health outcomes in general. Conducting follow-up assessments at the level of individual trauma services presents a number of other problems, including standardisation of eligibility criteria, and external validity of findings. Although the process described here was considered feasible at this trauma centre, it would be difficult to ascertain the burden of injury at a regional level or indeed any outcomes of trauma system interventions without a more unified approach [29, 30]. Whilst other studies have used the date of injury as the reference point for follow-up of severely injured patients, the reference point for this study was the date of discharge from hospital. This was because the study was to form the basis of piloting specific early post hospital discharge clinical interventions, and most of the patients in this study population were mild to moderate trauma with median length of stay of around 4 days. Finally, the number of predictor factors assessed was large relative to the number of cases followed up, and although there are no guidelines with respect to the number of variables allowed in mixed modelling methods, the study methods was largely consistent with similar studies [17, 21].

In conclusion, there was no change in PCS and MCS scores between 3 and 6 months post-discharge from hospital in this population of trauma patients. The predictors of poorer physical health were increasing injury severity scores and lower limb injuries and predictors of poorer mental health were related to mechanism of injury (assault and pedestrian mechanisms) and past mental health diagnoses. Further studies are required to determine whether specific predictors of poor health status, particularly mental health scores and return to work are amenable to early post-discharge clinical intervention.

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Compliance with ethical standards

The study was approved by the Sydney Local Health District Research Ethics Committee.

Conflict of interest Michael Dinh, Kevin Cornwall, Kendall Bein, Bernadette Tomes, Belinda Gabbe, Rebecca Ivers declare that they have no conflict of interest.

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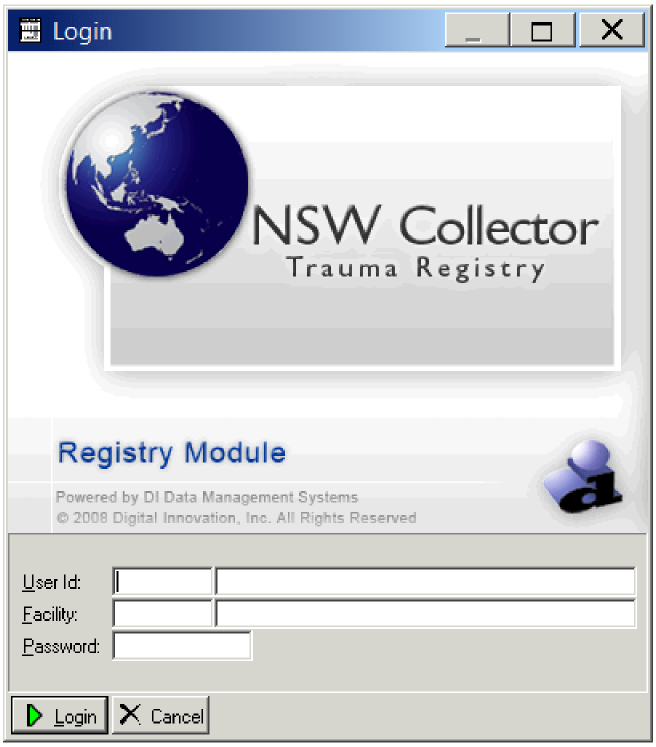
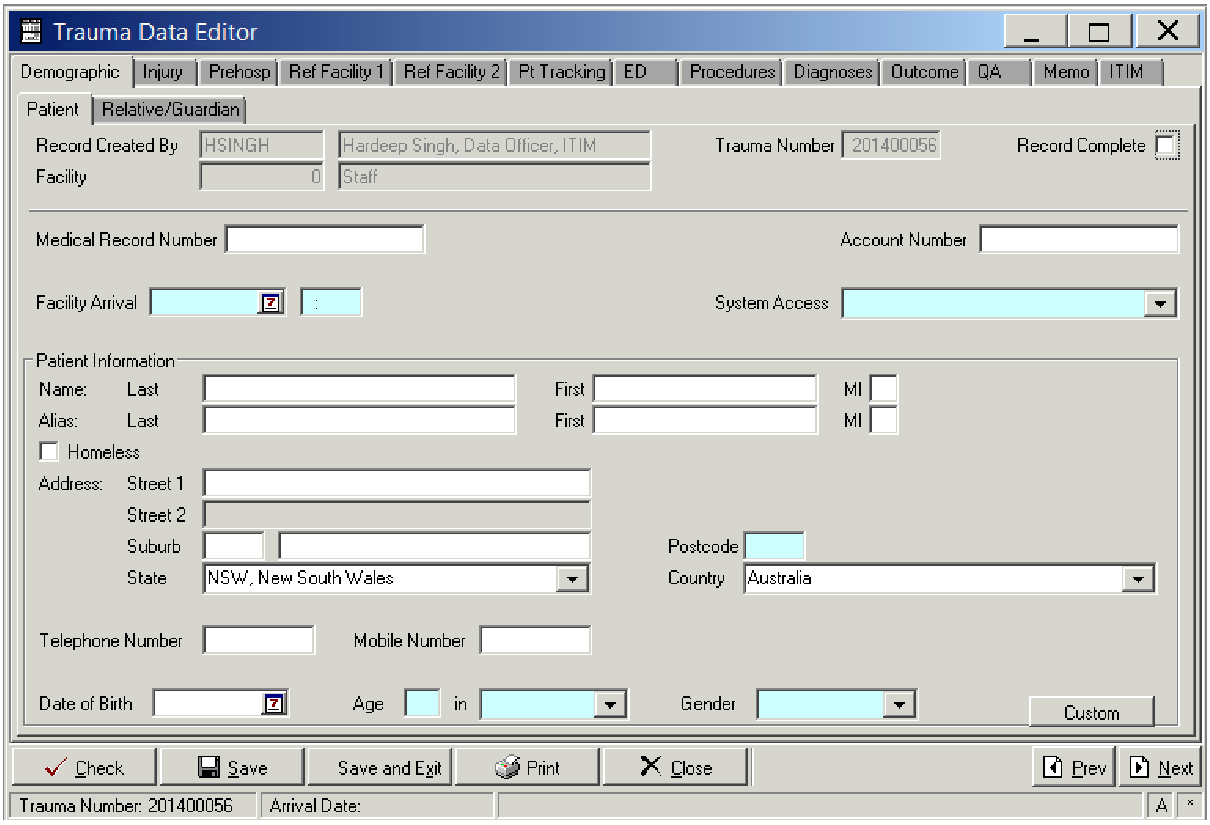
RPA TRAUMA QUALITY IMPROVEMENT PROGRAM

DATA MANAGEMENT SUPPLEMENTARY INFORMATION

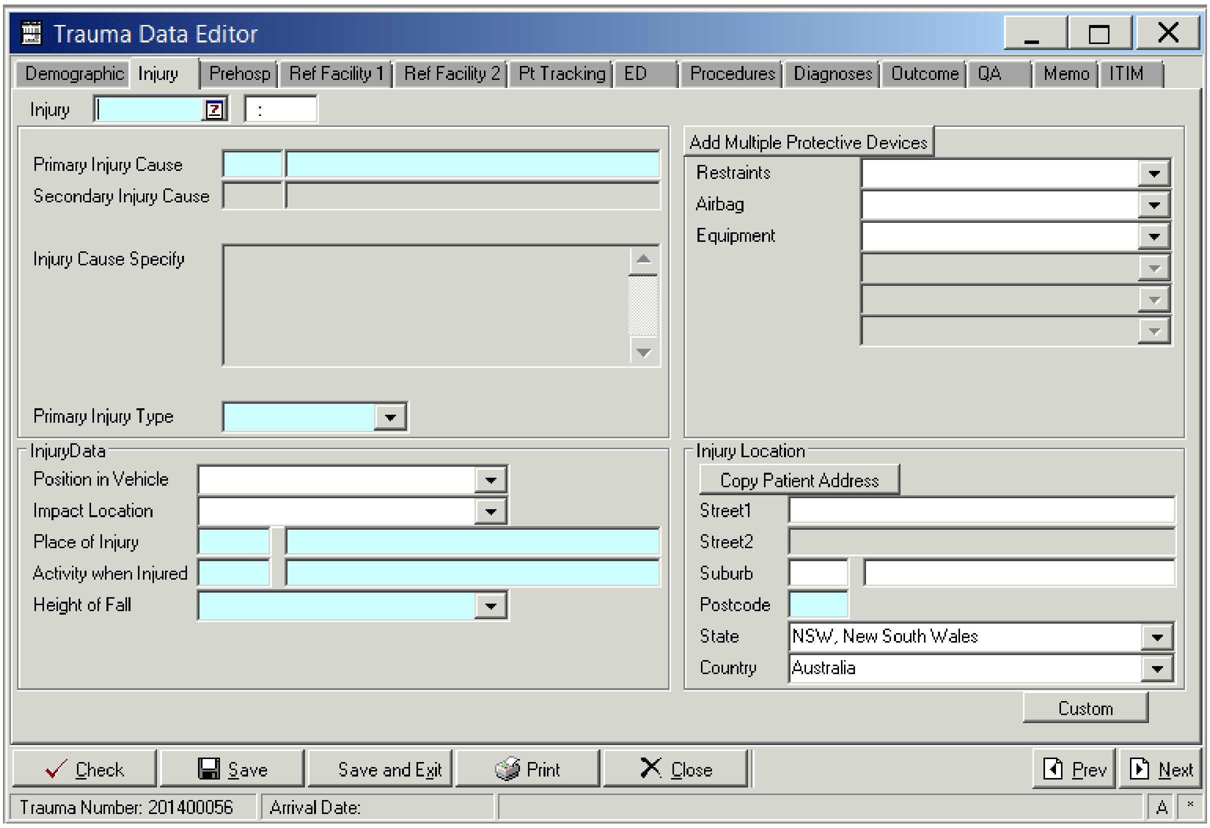
Screenshots of current State-wide trauma registry implemented at this institution in 2010



LOG IN SCREEN



DEMOGRAPHIC DATA



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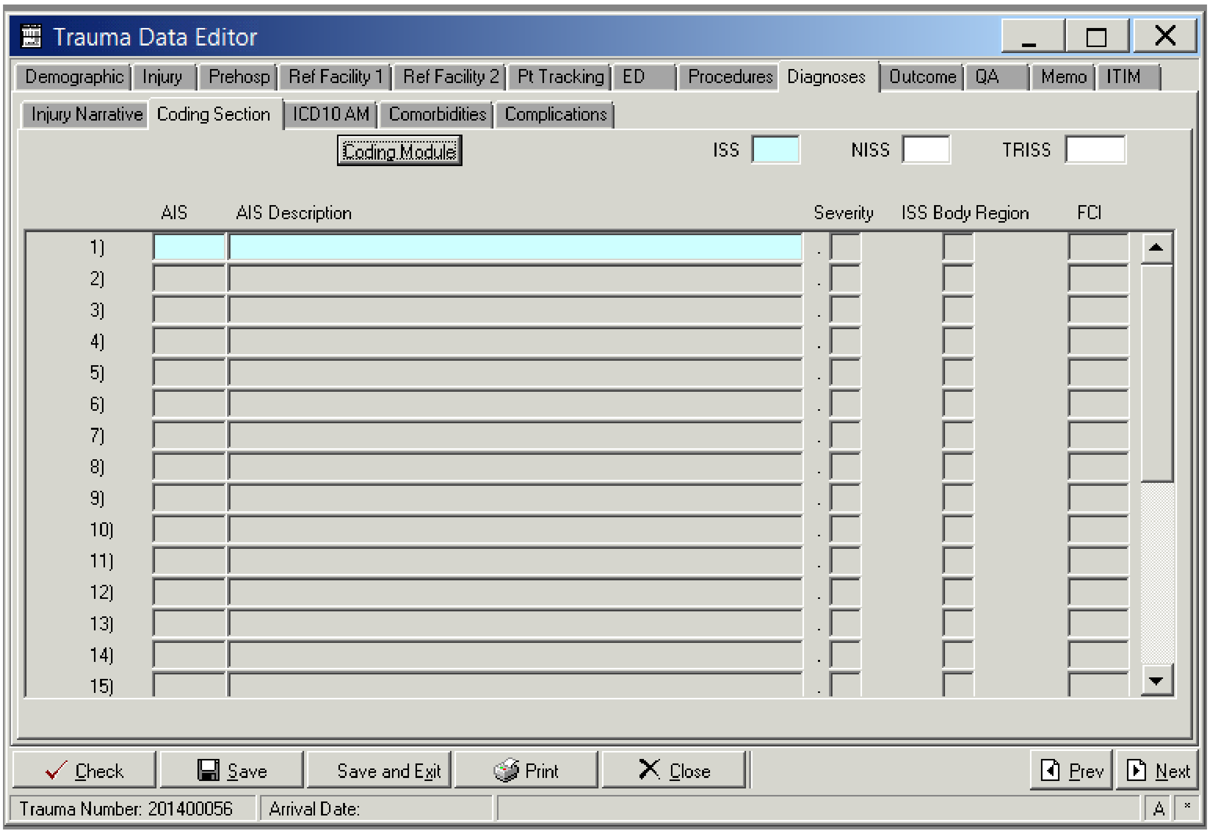

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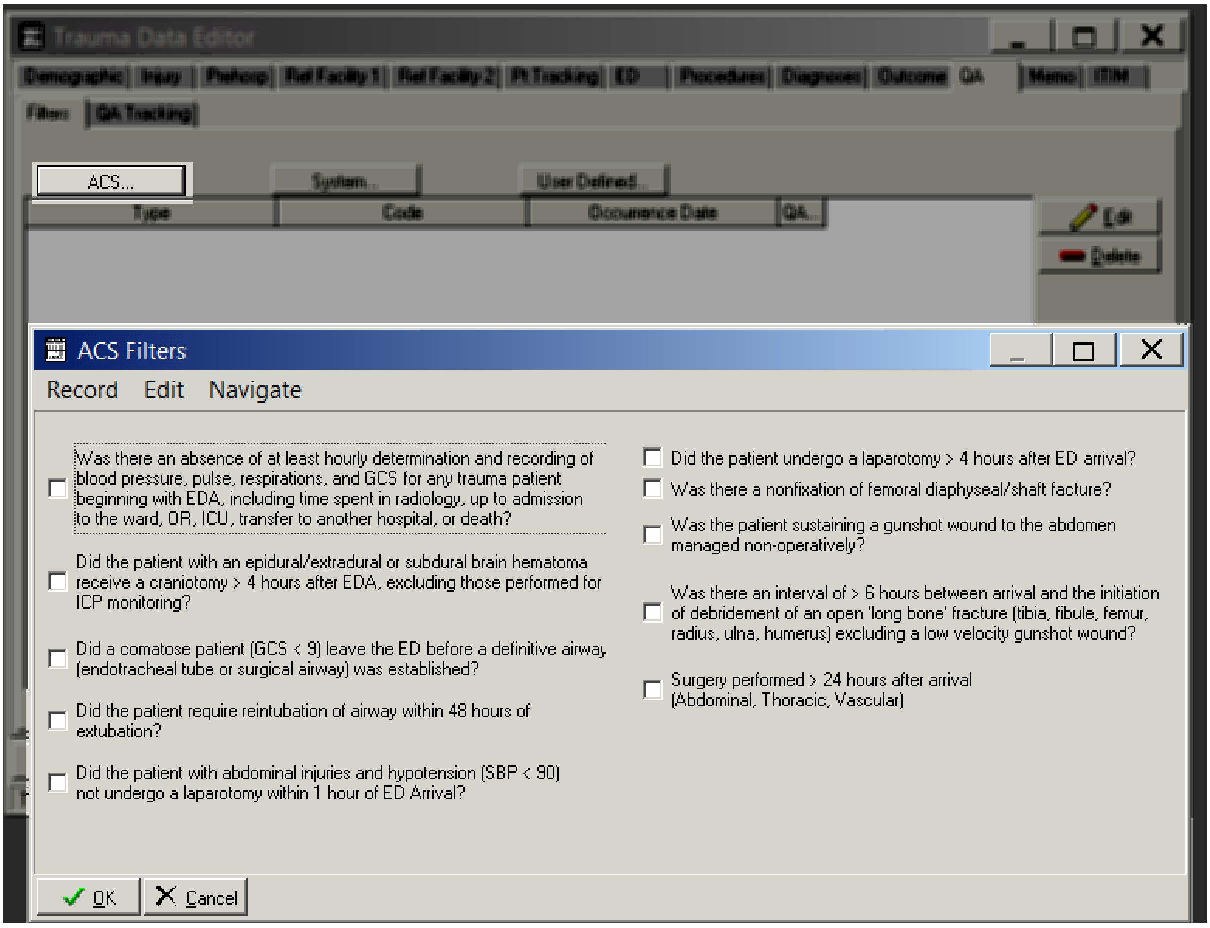
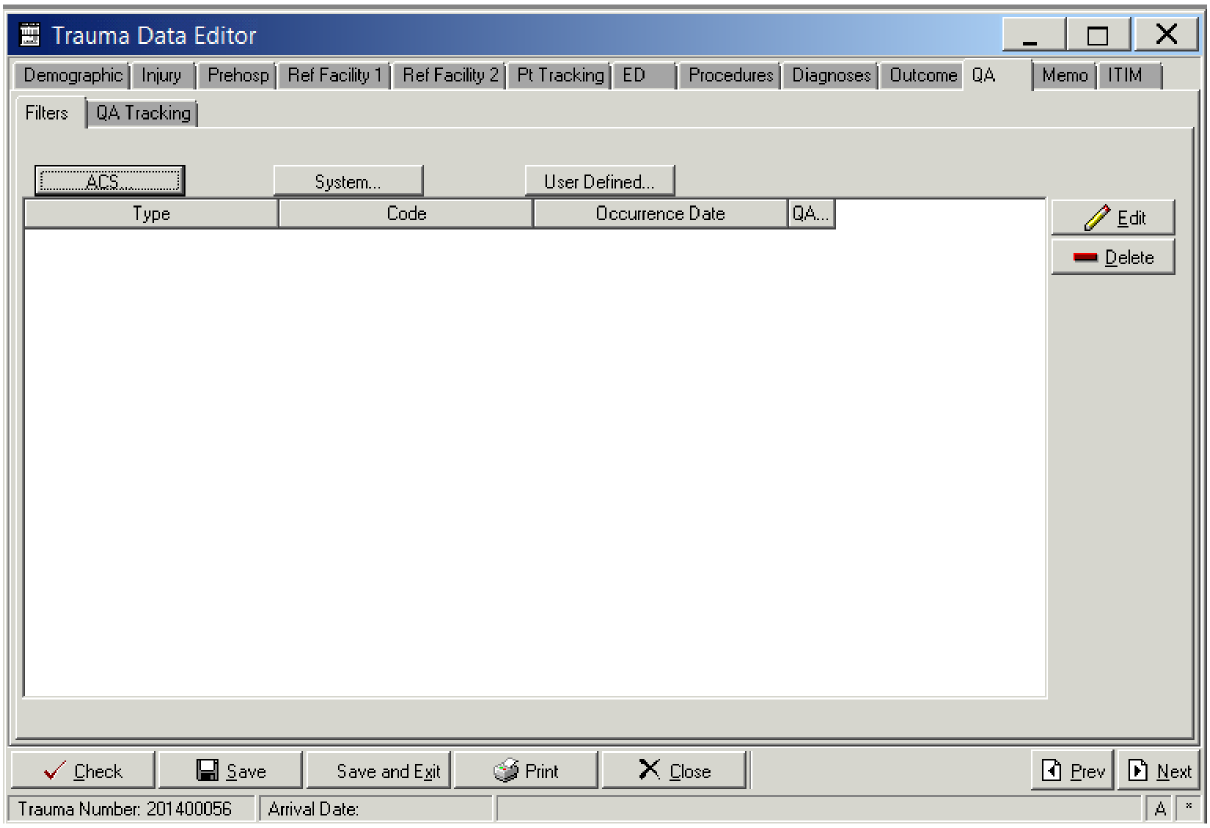
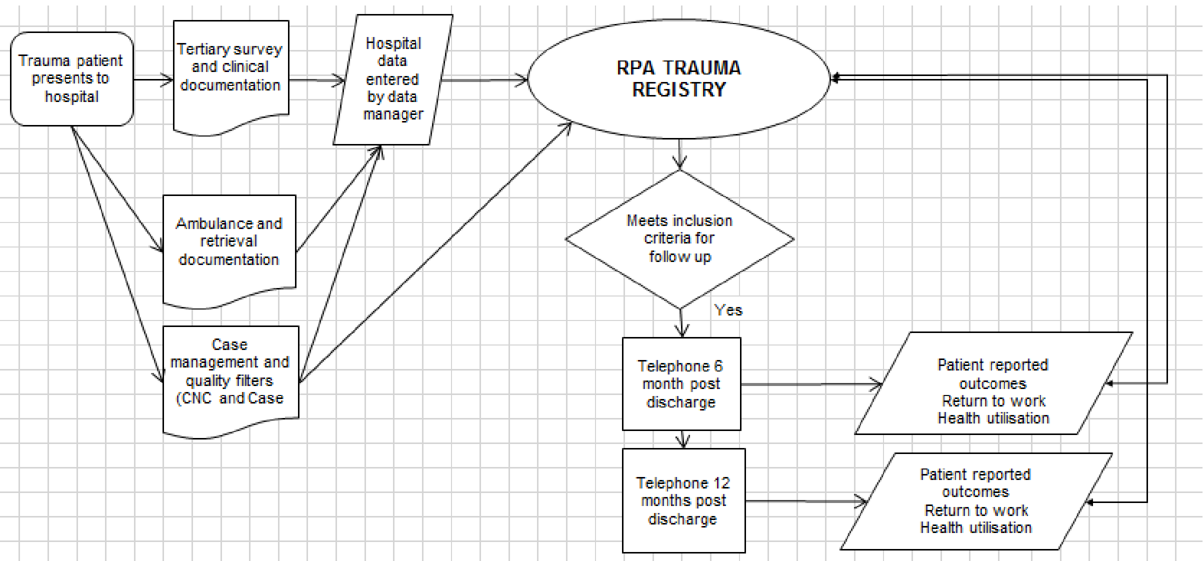


STATE-WIDE TRAUMA QUALITY FILTER SCREEN



INSTITUTION SPECIFIC QUALITY FILTERS SCREEN



DATA FLOWSHEET