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A REVOLUTIONARY APPROACH TO IMPROVE COMBAT CASUALTY CARE



TIMOTHY J. HODGETTS



CITY UNIVERSITY
LONDON

Has
medicine
advanced
too
far
that we can save
a man's life who
has only one limb
and no
balls?

●●

If
asked would
most soldiers
prefer
to
DIE
than to live this life?
THAT TAKES BALLS.

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**A REVOLUTIONARY APPROACH TO IMPROVE
COMBAT CASUALTY CARE**

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PhD BY PRIOR PUBLICATION

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OCTOBER 2012

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Declaration

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Abstract

Background: Military medicine has historically advanced in war. Advances in concepts, technology, organisation and operational processes have occurred during the contemporary conflicts of the last decade. **Aims:** To determine whether the advances constitute a 'Revolution in Military Medical Affairs (RM2A)'; to demonstrate my role within a revolutionary transformation; and to introduce new theory to determine if advances have been appropriately matched to clinical need.

Definition: An RM2A is defined here as a radical change in the character or practice of military medicine. **Methods:** 20 papers are selected (15 first author; 5 second author) that describe the changes in modern combat casualty care. These are clustered into conceptual (doctrine) innovation; changes to organisational structure and operational processes; and advances in technology. These are analysed against Lambeth's (1997) criteria for a Revolution in Military Affairs (RMA); Cohen's (2009) three tests for an RMA, but adapted for an RM2A; and Toffler's (1993) criteria for a 'true revolution'. The null hypothesis for the novel theory (*Homunculus Casualty Theorem*) states that the concept, training, equipment and practice changes within the RM2A are not correspondingly or proportionately matched in importance to the immediately life-threatening injuries and physiology of contemporary combat trauma.

Results: The creation of new concepts (<C>ABC, DCR) and doctrine (MIMMS, 1st Aid) are demonstrated, incorporating a raft of novel heuristics. Developments in trauma governance are described that have provided both the evidence to drive change and the proof of effect of change. Specific evidence for avoidable in-hospital cardiac arrest is presented, together with an organisational solution for prevention that highlights the NHS barriers to innovation adoption. The results of system transformation are demonstrated as a cohort of 75 unexpected survivors of critical combat injury; traumatic cardiac arrest survival of 24% is unexpectedly high.

Conclusions: An RM2A is proven that meets the sentinel criteria. The scope of advances in combat casualty care has appropriately reflected clinical need particularly for the rapid and effective treatment of haemorrhage, although battlefield analgesia has failed to advance. Most importantly, it is asserted that the proven RM2A is responsible for the unexpected positive outcomes following critical combat injury. There is evidence I have played a central role in this transformation of military medicine. Effort to transfer the learning into NHS practice has begun.

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Abbreviations

ABC	Airway, Breathing, Circulation
ADMEM	Academic Department of Military Emergency Medicine
ALSG	Advanced Life Support Group
ASCOT	A Severity Characterisation of Trauma
BATLS	Battlefield Advanced Trauma Life Support
<C>ABC	Catastrophic Haemorrhage, Airway, Breathing, Circulation
CGOs	Clinical Guidelines for Operations
CI	Confidence Interval
COTS	Commercial Off the Shelf
CPR	Cardiopulmonary Resuscitation
CSCATTT	Command, Safety, Communications, Assessment, Triage, Treatment, Transport
CT	Computed Tomography
CTRs	Casualty Treatment Regimes
DCR	Damage Control Resuscitation
DCS	Damage Control Surgery
DLoDs	Defence Lines of Development
DMS	Defence Medical Services
DNBI	Disease or Non-Battle Injury
Dstl	Defence Scientific and Technical Laboratory
ED	Emergency Department
FCOMM	Future Character of Military Medicine
GSW	Gunshot Wound
HCC	Healthcare Commission (now the Care Quality Commission)
HCDC	House of Commons Defence Committee
HEMS	Helicopter Emergency Medical Service
IED	Improvised Explosive Device
IRA	Irish Republican Army
ISS	Injury Severity Score
ITD(3)	Individual Training Directive 3, Individual First Aid
ITU	Intensive Therapy Unit (synonymous with Intensive Care Unit)
JDP	Joint Defence Publication
JSP	Joint Service Publication
JTCCC	Joint Theatre Clinical Case Conference
JTTR	Joint Theatre Trauma Registry
KPI	Key Performance Indicator
MACE	Major Trauma Audit for Clinical Effectiveness
MERT	Medical Emergency Response Team
MET	Medical Emergency Team

METHANE	Major incident declared, Exact location, Type of incident, Hazards present and potential, Access and egress, Number and severity of casualties, Emergency services present and required
MIMMS	Major Incident Medical Management and Support
MIST	Mechanism, Injuries, Signs, Treatment
MoD	Ministry of Defence
MOTS	Military Off the Shelf
NAO	National Audit Office
NATO	North Atlantic Treaty Organisation
NCEPOD	National Confidential Enquiry into Patient Outcomes and Deaths
NICE	National Institute of Clinical Excellence
NHS	National Health Service
NISS	New Injury Severity Score
OR	Operating Room
OR	Odds Ratio (when immediately followed by a figure)
PJHQ	Permanent Joint Headquarters
PTT	Paediatric Triage Tape
RCDM	Royal Centre for Defence Medicine
RCSE	Royal College of Surgeons of England
R&D	Research and Development
rFVIIa	Recombinant Factor VIIa
RMA	Revolution in Military Affairs
RM2A	Revolution in Military Medical Affairs
SDR	Strategic Defence Review
SGD	Surgeon General's Department
TEG	Thromboelastography
TPR	Temperature, Pulse, Respirations
TRaPS	Tactical Rapid Primary Survey
UK	United Kingdom
VUCA	Volatile, Uncertain, Complex, Ambiguous
WW1	World War 1
WW2	World War 2

PART A



BACKGROUND

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1 Introduction

1.1 Purpose of the study

This study evaluates the profound changes in the early management of combat injury within the United Kingdom (UK) Defence setting in the decade from 1999-2009.

Fundamentally it aims to prove that these changes are genuinely 'revolutionary' and determines my role as a leader of revolutionary change through analysis of a body of published work.

Individual components of conceptual, organisational and practical change described in this study have contributed to improved outcomes in critical injury. The work explains the objective basis for claiming improved outcomes; benchmarks performance to civilian norms; investigates how specific components have added value; demonstrates the complexity of change through a chronology of serial innovation; and postulates how civilian healthcare systems can learn from military operational experience.

Collectively, the work is a synthesis of systematic developments in contemporary combat casualty care attributable to the author. It represents a unique organisational history and reveals the logic of the underpinning academic model to drive comprehensive change across all Defence Lines of Development.¹ Through the supporting framework of publications, this study aims to demonstrate my contribution to furthering medical knowledge within the domain of combat casualty care.

"It will be tragic if medical historians can look back on the World War II period and write of it as a time when so much was learned and so little remembered."

Henry Beecher (1951). Early Care of the Seriously Wounded Man

The author's contribution to developing combat casualty care is extended over time and is complex: the elements are interlinked and paint a complete picture over time. Table 1.1 is an overview of the author's responsibility for key development milestones and relates them to the publications presented in this thesis that prove an addition to the body of medical knowledge.

¹ The Defence Lines of Development are Training, Equipment, Personnel, Infrastructure, Doctrine, Organisation, Information and Logistics (TEPID OIL).

Year	Author innovation	Related thesis publications
1998	New concept and new equipment . Development of Paediatric Triage Tape.	Journal article (Paper 1)
1999	New concepts and new curriculum . Battlefield First Aid made simple and systematic. 'Control then ACT' concept introduced.	Journal article (Paper 2) Supporting book: Battlefield First Aid Drills
2000	New process of operational governance. A system for trauma governance introduced on operations in Kosovo.	Journal article (Paper 3)
2000	New concepts and new curriculum . An international, all-hazard system of multiple casualty management is developed and its effectiveness evaluated. Concepts include 'METHANE message' and 'CSCATTT'.	Journal article (Paper 4) Supporting books: Major Incident Medical Management & Support; Major Incident Management System
2002	New evidence to prevent cardiac arrest & new national curriculum.	Journal articles (Papers 5 & 6)
2005	New understanding of the requirements for treating civilians during military operations.	Journal article (Paper 7)
2005	Leadership for adoption of new equipment . Leadership to rapidly introduce topical haemostatics and evaluate clinician attitudes to implementation.	Journal article (Paper 8)
2006	New concept . Developed and introduced <C>ABC concept. Widespread impact on clinical training, equipment and practice.	Journal article (Paper 9)
2006	New concepts, curriculum & practices . BATLS course fundamentally revised. New concepts/practices propagated included <C>ABC, MIST and TRaPS.	Journal articles (series relates to Paper 10) Supporting books: Joint Services Publication 570; Joint Doctrine Publication 4-03.1
2007	Improved standards of trauma governance. A template for best practice is described.	Journal article (Paper 11)
2007	Improved clinical practice and improved protection from injury. Analysis of systematic post mortem examination of military operational deaths.	Journal article (Paper 12)
2007	New understanding of evacuation timelines in order to improve them.	Journal article (Paper 13)
2007	Leadership for adoption of new equipment . Leadership to rapidly introduce commercial tourniquets and evaluate their effectiveness.	Journal article (Paper 14)
2007	New concept . Damage Control Resuscitation developed and introduced.	Journal article (Paper 15)
2007	New practice . Guidance for the use of recombinant Factor VIIa in combat trauma developed and introduced.	Journal article (Paper 16)
2007	New understanding of differences between military and civilian trauma care.	Journal article (Paper 17)
2009	New understanding of the differences between military and civilian pre-hospital care.	Journal article (Paper 18)
2010	New process of operational governance introduced (Joint Theatre Clinical Case Conference) with evidence of its effectiveness.	Journal article (Paper 19)
2011	New evidence of improved clinical outcome as summative effect of other process, equipment and practice changes introduced by author.	Journal article (Paper 20)

Table 1.1: Key Milestones in Combat Casualty Care—Author's Contribution

Note: The numbered articles referred to in the 3rd column are listed in full in Table 2.1.

Supporting books are listed in the Reference section.

The developments in combat casualty care have been non-linear. An analogy is drawn to completing a painting over a ten-year interval, one colour at a time, until a clear picture is interpretable. This is an image of success (Figure 1.1).



Figure 1.1: Building a picture of success for combat casualty care

[Colonel Hodgetts shown with 'Pride of Britain' award to the Field Hospital in Afghanistan, 2009]

1.2 Uniqueness of the study

The concept of a *Revolution in Military Medical Affairs* is novel to this thesis. In addition, a new theory has been framed for the thesis to evaluate whether the direction of the 'revolution' has matched the clinical need—the *Homunculus Casualty Theorem*. Together these introduce a new vernacular and prism through which to view past and future developments in combat casualty care, reinforcing the contribution to the body of medical knowledge.

Research questions

Has there been a *Revolution in Military Medical Affairs*?

How does this body of work contribute to the revolution?

1.3 Constraints

Critical analysis of supporting publications is constrained by required brevity: it is necessarily selective and subjective to my preference.² The works selected are a balance between publications that represent the greatest contribution to changing medical practice, while meeting the conditions of first or second authorship.

² A list of personal publications is at Annex A (books, book chapters and peer-reviewed papers only).

1.4 Background

An enduring certainty of war is casualties. The responsibility of treating UK combat casualties falls to the Defence Medical Services (DMS). In 1994 a Defence spending review reduced the DMS by such a degree that in 1997 the House of Commons Defence Committee (HCDC) questioned whether the organisation could survive as a separate entity. Further, it was concluded that:

“...the DMS are not sufficient to provide proper support to the front line in all realistic planning scenarios and show little prospect of being able to do so in the future.” (HCDC, 1999, p.vii)

The Committee later expressed that the DMS would have been incapable of supporting a ground invasion of Kosovo in 1999, rather than the less resource demanding stabilisation operation that was undertaken after over 2 months of sustained bombing.

In response to initial criticism, the DMS began to develop a strategy for organisational restructuring and capability enhancement (UK MoD, 1998). This included an innovation to represent the NHS Executive on the Defence Medical Board with the intention of ensuring that DMS policies accorded with NHS best practice. The strong inference that the perceived deliverable standard of DMS care was below that of the NHS was being reinforced.

Ten years later in 2009 the Healthcare Commission (HCC), now the Care Quality Commission, published a comprehensive review of the treatment of combat casualties from point of wounding to rehabilitation. The report stated that the standard of treatment for those seriously injured on operations overseas was now ‘exemplary’, the results achieved were the ‘best ever reported’ and that this was a ‘truly remarkable achievement’ (HCC, 2009, p.13). Paradoxically, it was recognised that the patient’s journey was now optimally efficient and ‘there is much that could be learned by the trauma services within the NHS’.

Additional objective evidence demonstrates that the injury severity of combat casualty survivors is rising (Kelly *et al*, 2008) and combat casualties as a group have statistically more serious injuries than civilians injured in the UK (**Hodgetts *et al*, 2007a, Paper 17**). Despite these trends, there is a growing cohort of combat

casualties since 2008 that are judged to be ‘unexpected survivors’ by mathematical modelling and clinical peer review (Russell, **Hodgetts** et al, 2011, **Paper 20**). The impact on survival of physical conditioning and limited comorbidity could be queried, but has not been quantified. Importantly however, there are casualties that could only have survived within the sophisticated military trauma system—with the deduction that they would have died if treated in the NHS. This is supported by the National Audit Office’s (NAO) independent comparison of system outcomes in 2010, which confirms favourable military system performance over the NHS (NAO, 2010). The stark contrast in assessment of DMS capability over this period implies profound change. To determine if this is ‘revolutionary’ change first requires definition of the related academic terminology.

1.5 Defining Revolution—RMA & RM2A

1.5.1 Revolution in Military Affairs

The term *Revolution in Military Affairs* (RMA) has been applied to contemporary advances in conventional warfare and is a starting point to defining a revolutionary approach to improving combat casualty care. However, RMA lacks a single attributable definition. At its simplest, Colin Gray (2006, p.105) describes it as:

‘A radical change in the character or conduct of war’.

Benjamin Lambeth’s (1997, p.75) definition usefully builds on this foundation and describes an RMA as:

‘The innovative application of technologies which, combined with dramatic changes in military doctrine and operational and organizational concepts, fundamentally alters the character and conduct of military operations’.

Andrew Krepinevich’s (1994, p.30) definition strongly resonates with Lambeth’s: he explicitly lists four components that must be present to satisfy a ‘revolution’. These components are given in Table 1.2 and are paired with Lambeth’s criteria. Doctrine is defined as ‘a belief or set of beliefs held and taught’ (Oxford English Dictionary, 2012): Lambeth’s ‘doctrine change’ does not accurately match Krepinevich’s ‘systems development’. All the transformation described in this thesis is linked to advancing the military trauma *system*: for this reason Lambeth’s criteria are used to determine revolutionary change as they offer slightly broader differentiation. The

colour codes employed in Table 1.2 are carried through this thesis to the evidence section to identify how each submitted paper meets an established criterion for revolution.

Lambeth's Criteria (1997)	Krepinevich's Criteria (1994)
Military doctrine change	Systems development
Operational concept change	Operational innovation
Organisational concept change	Organisational adaptation
Technology innovation	Technological change

Table 1.2: *Criteria for a Revolution in Military Affairs*

Alternative definitions vary little other than semantics. What all share in common is recognition that an RMA is more than technological change, as is implied from the original Soviet use of the term 'military technical revolution' in the 1960s. Max Boot (2006) proposes that it is not technology *per se* that creates a revolution, but how organisations respond to technological advances: this depends on their organisation, leadership, morale, training and human factors. Alvin and Heidi Toffler (1993) view the technological aspect of RMA from a different perspective. They note that more often than not an invention has only created a better or more efficient way of doing the same things within the 'existing game'—and these are more accurately classified as 'sub-revolutions'. For a 'true revolution' the innovation must change the rules of the game, its equipment, the size and organisation of the teams, their training, doctrine and tactics.

1.5.2 Revolution in Military Medical Affairs

Beaty (1997) is the first to consider RMA from a medical perspective. He predicted a *potential* revolution in relation to changes in the geostrategic environment, information technology and medical practice that would shape how US medical services may be configured and employed in peace and conflict in the 21st Century. Zalmay and White (1999) also acknowledged, but without any analysis, that RMA may extend into the medical domain.

The generic nature of the RMA definitions supports analysis of military medical advances within the same framework. However, the spirit of interpretation is very different. In the traditional sense, RMA generates a step change in the character of war that reflects a more effective or efficient means for inflicting human harm. This is the polar opposite to the central precept of medicine—*primum non nocere*, 'first do no harm'. To accommodate this incongruity it is appropriate to extrapolate Gray's

(2006) parsimonious definition to express the concept of a *Revolution in Military Medical Affairs* (RM2A) in a novel way as:

A radical change in the character or practice of military medicine.

1.6 Plotting the revolution

Elinor Sloan (2002, p.24) notes that 'most RMAs take considerable time to develop, even in wartime'. For the DMS it has been a ten-year change process against a background of uninterrupted expeditionary operations, with a cluster of step changes I have led to transform military trauma care occurring between 1999 and 2009. Civilian trauma care marked time in this decade of military change, being repeatedly criticised by the *Royal College of Surgeons of England* (RCSE) and the *National Confidential Enquiry into Patient Outcome and Death* (NCEPOD) for its failings:

'There is no national strategy for the care of the severely injured...mortality varies inexplicably between hospital Trusts.'

RCSE, 2000, p.10

'The organisation of pre-hospital care, the trauma team response, seniority of staff involvement and immediate in-hospital care was found to be deficient in many cases.'

NCEPOD, 2007, p.8

A strategic drift has resulted whereby DMS concepts, equipment and practices have diverged from the NHS baseline to produce a military trauma system that has enhanced capability across the Defence Lines of Development when compared with civilian peer systems. This drift is plotted on Figure 1.2. Prior to 1999 there was no evidence of military system performance, only the presumption that care would fall below civilian standards from the DMS' aspiration in the 1990's to provide as near best NHS practice standards as possible within operational environment constraints. Comparable care standards were proven to be achievable in Kosovo in 1999 (Hodgetts *et al* 2000, **Paper 3**): serial innovation predominantly from 2006 has created the drift, with military standards diverging from civilian norms to create unexpected positive outcomes (Russell, **Hodgetts et al, Paper 20**). While the focus

of this study is on proving transformational change, it is recognised that continuity is as important as innovation in many aspects of medicine (for example, in history taking and physical examination) and that incremental changes have continued after 2009.

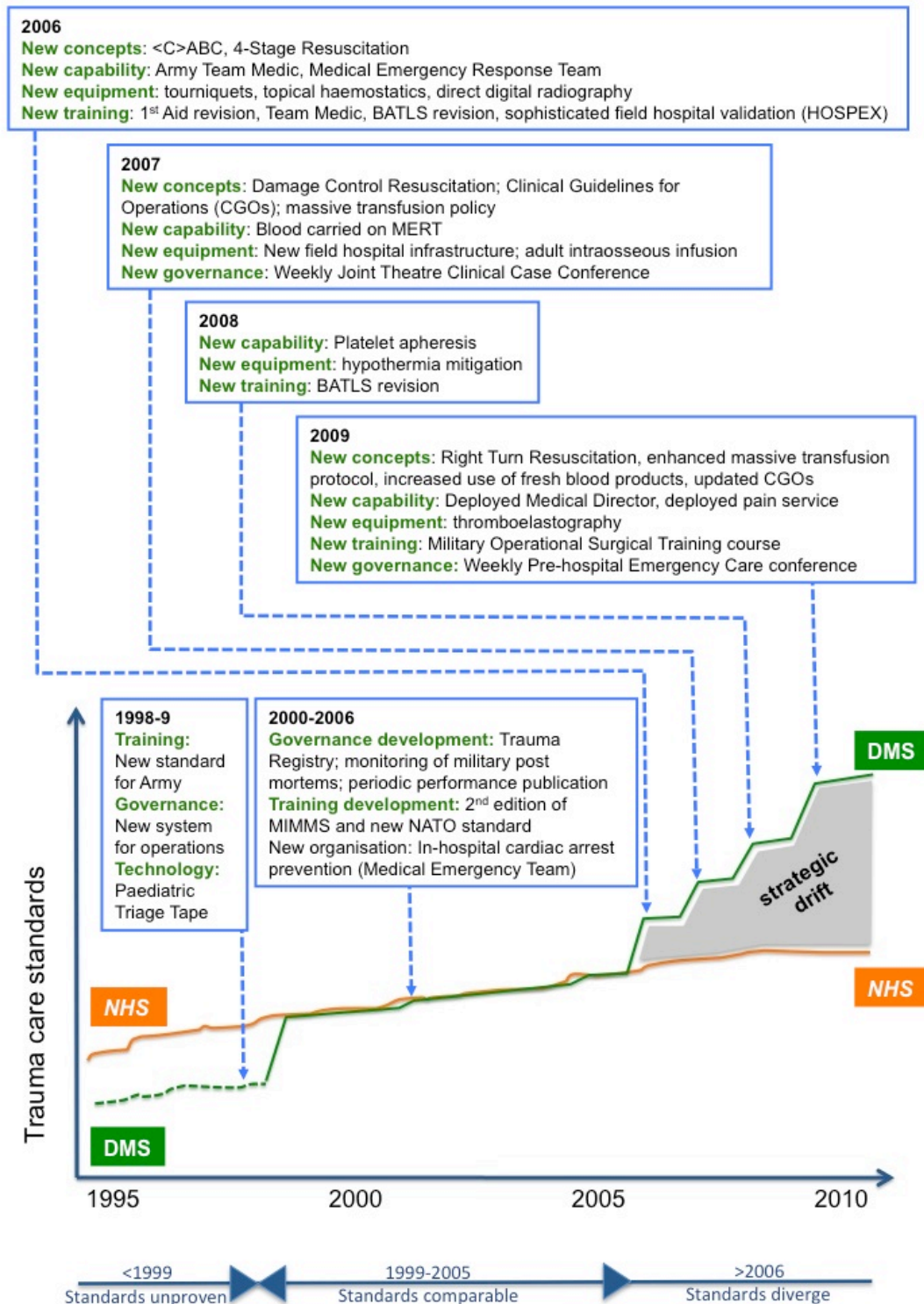


Figure 1.2: Strategic drift of military and civilian trauma systems

Figure 1.3 shows how the principal 20 papers referred to in this thesis contribute to the cumulative innovation within the Defence Medical Services that has generated the strategic drift in practice and outcome.

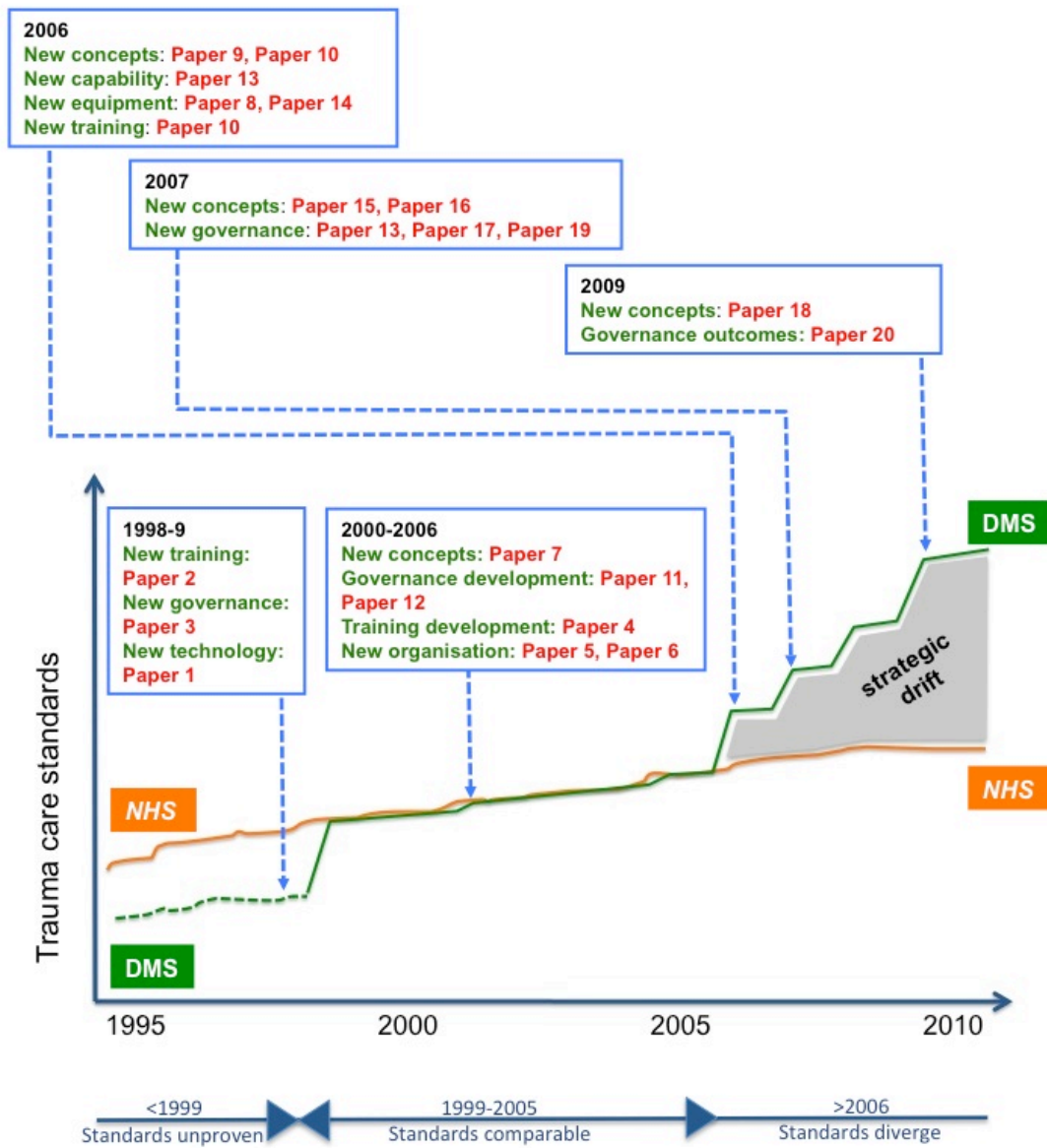


Figure 1.3: Cumulative innovation, strategic drift and the relationship of thesis literature

2 Methodology

2.1 Measuring Revolution

The definitions of RMA and RM2A provide indices against which to judge revolutionary change. Whether the advances in combat casualty care I have led span all of Lambeth's components of RMA, and whether the change in character of military medicine classifies as a 'true revolution' rather than a 'sub-revolution', will be determined. Eliot Cohen (2009, p.22) described three questions that when tested determine whether RMA has occurred, and can be adapted for RM2A to compliment the analysis (the text in square brackets represents adaptation):

- ① "Do military [medical] forces look fundamentally different?"
- ② "Are the processes of 'battle' different?"
- ③ "Are [clinical] outcomes different?"

Importantly, Cohen's approach extends the opportunity for analysis from observations of change in 'character' (structures, technology) and 'conduct' (doctrine, processes) to encompass 'effect' (clinical outcome). While elements of a traditional RMA may be difficult to quantify, such as the impact of enhanced information systems on military operational success, clinical outcomes are amenable to rational analysis using accepted international metrics (Smith, **Hodgetts et al**, 2007, **Paper 11**).

Nevertheless, an evaluation of RM2A cannot be entirely rational. In some respects assessing the impact of changes in combat casualty care is a 'VUCA' problem (**V**olatile, **U**ncertain, **C**omplex, **A**mbiguous). Evolving weapons of our adversary, and improvised explosive devices (IEDs) in particular, produce a future *uncertainty* of injury patterns. In parallel it is arguable, without declaring vulnerability to specified mechanisms, that recent success is contingent on certain weapon configurations reproducing certain 'treatable' injuries—that is, there is an *ambiguity* of outcome that may change as weapons evolve. Change is *volatile*, and perhaps more accurately fragile, because it has been largely confined to military medicine and lacks the durability of being embedded in NHS peacetime practice. *Complexity* is apparent in the scope of concept, practice and technology changes that have been implemented near-simultaneously, which frustrates the ability to quantify the impact of individual innovations.

Selection bias in measuring the effect of revolution is accepted as a potential limitation of this study. However, proof of RM2A is dependent on positive examples that criteria are met, for example an improvement in clinical outcome, which this study aims to provide from my published work.

2.2 RM2A Academic Model

“A working theory is an essential basis for criticism”

Clausewitz (1832), Book V³

Within the subject period of study I have developed and applied an academic model that links parallel strands of development into an overarching model of systemic capability enhancement (Figure 2.1). While this model was emergent rather than prospective in design, it has engineered the framework that links the complex system’s interdependent components. As the evidence for conceptual, doctrinal, equipment, practice and clinical governance change will be necessarily evaluated in a linear manner, the model provides a strategic appreciation of the multi-dimensional dependence and iterative continuous development that occurs within the system.

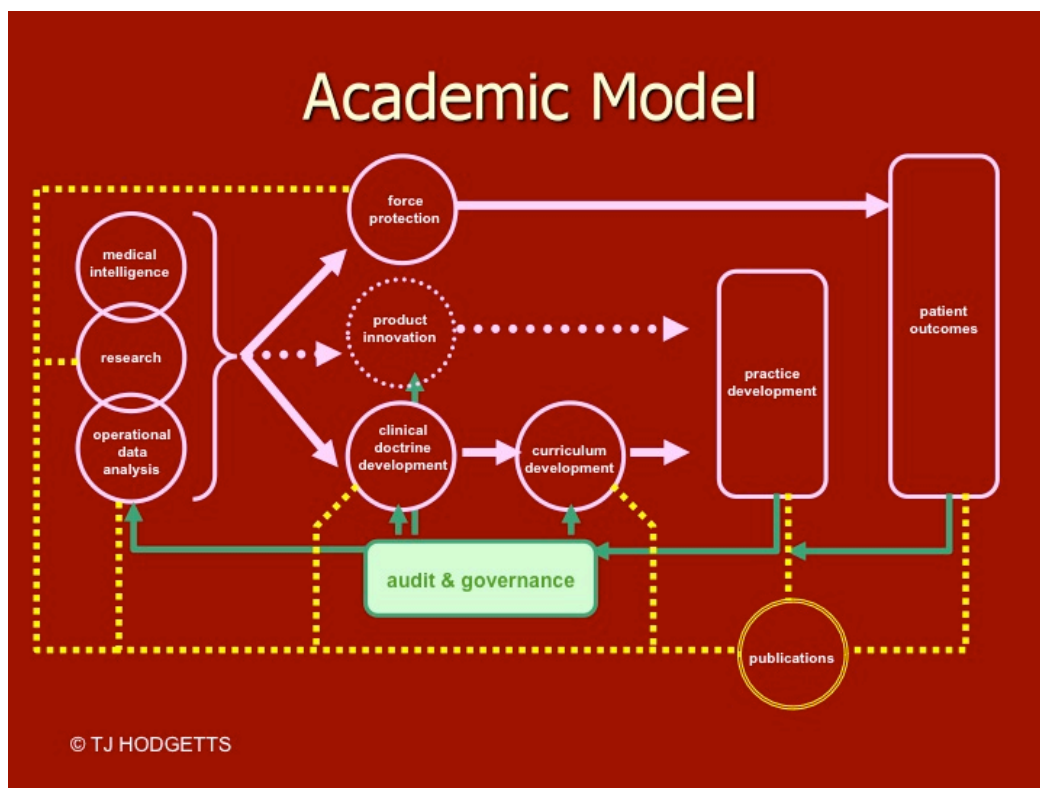


Figure 2.1: RM2A Academic Model

³ Clausewitz’s *On War* was published posthumously in 1832; there are numerous translations.

Inputs to the model are medical intelligence⁴ and continuous analysis of detailed data relating to all serious injuries and trauma deaths (*post mortem* findings) on expeditionary operations. These inform research priorities within the Defence Scientific and Technical Laboratory (Dstl), which commonly involve animal modeling of critical injury. The combined interpretation of intelligence, operational data analysis and novel research creates opportunities for concept and doctrine development, innovation in clinical equipment, and reduction of future injury risk through identification of vulnerabilities in vehicle and personal protective systems. Changes in clinical doctrine (guidelines) are reflected in a responsive step-wise curriculum that encompasses all acute care interventions from first aid through to field hospital resuscitation and enforces new standards of practice prior to deployment. Continuous near real-time clinical audit operates as a safety net and supports rapid response adjustments to doctrine, training or equipment in the event of any unexpected adverse clinical event; it also provides the substrate for detailed clinical trend analyses. A raft of core publications that can be dynamically modified supports the model in order to distribute the adapting body of knowledge and encourage a learning organisation. These publications, where I can claim creation and serial incremental development, will be discussed in the body of the thesis.

It is postulated that the system's detailed feedback and rapid adaptability underpins its exemplary performance, and is determined by the ability to develop, control and measure (where measurable) all of the model's components in tandem. There is no reliable test of this assertion other than to re-evaluate performance on removing a component from the process—and there is no ethical justification to do this. The evidence presented for improved outcome will not be attributed to a single component or selection of components, but rather to the harmony of the system. This is an assumption conditional on the VUCA nature of the analysis.

2.3 The *Homunculus Casualty Theorem*

A new theory is proposed and tested in the context of RM2A, the *Homunculus Casualty Theorem*. A homunculus is a distorted body image where proportions relate to how the parts of the body are relatively represented within the brain. Analogously, injuries and changes in physiology are of unequal importance to a combat casualty's outcome and the importance of treatment of these is therefore also relative (Figure

⁴ Medical intelligence in this context comprises deployed clinical experience; scientific papers; grey literature from allies; and official body recommendations (NICE, Royal Colleges, professional associations).

2.2). This is quite separate from the historical representation of the range of combat injury *mechanisms* (Figure 2.3). What is to be determined is whether my contribution has been focused in appropriate proportion on those injuries that are the greatest immediate threat to life. This is expressed in the null hypothesis:

Homunculus Casualty Theorem: Null Hypothesis

The concept, training, equipment and practice changes within the RM2A are not correspondingly or proportionately matched in importance to the immediately life-threatening injuries and physiology of contemporary combat trauma.

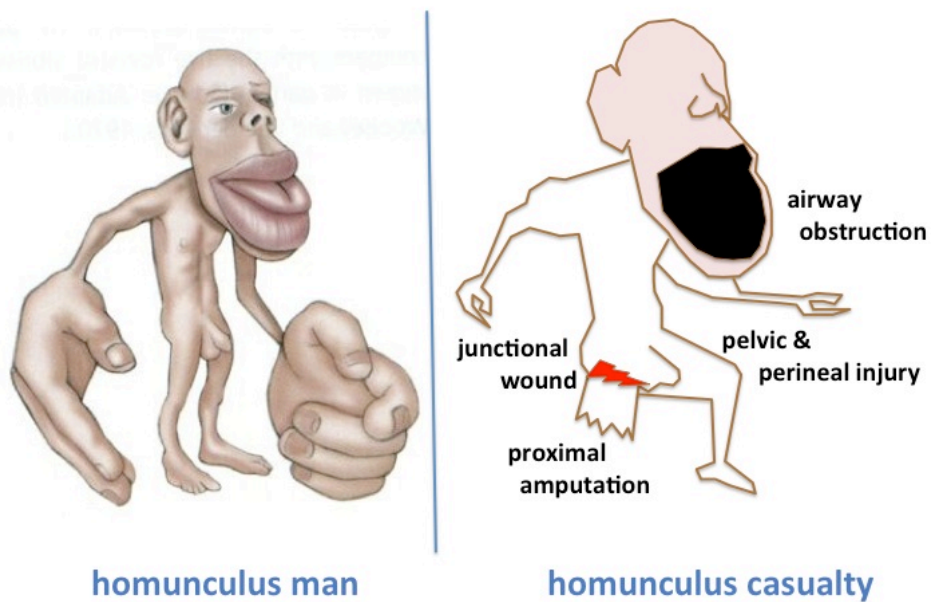


Figure 2.2: Homunculus Man and Homunculus Casualty



Figure 2.3: Wound Man

From 'Feldbuch der Wundartzney', 1530

2.4 Supporting papers

Twenty papers are selected to support this thesis and are listed in Table 2.1. They are referred to as 'Paper 1' through 'Paper 20' in chronological publication order.

However, to facilitate evaluation of whether a *revolutionary transformation* has been achieved the papers are **not considered chronologically**, but are grouped and **evaluated functionally** in three chapters conforming to Lambeth's (1997) definition of RMA. The colour codes from Table 1.2 are used to reinforce the functional area to which each paper refers:

- **Chapter 3:** Doctrinal Revolution (new concepts) **DOCTRINE**

- **Chapter 4:** Organisational & Operational Revolution (systems development, operational innovation and organisational adaptation) **ORGANISATION**
OPERATIONS

- **Chapter 5:** Technological Revolution (new equipment) **TECHNOLOGY**

Additional material I have published is referenced within the text where it contributes to the discourse, without being included as an assessed component of the submission: a list of my publications (books, book chapters and peer-reviewed papers only) is at Annex A.

Serial	Paper title	Innovation domain
1	The Paediatric Triage Tape. <i>Pre-hospital Immediate Care</i> 1998;2:155-159.	TECHNOLOGY
2	Battlefield first aid: a simple systematic approach for every soldier. <i>Journal of the Royal Army Medical Corps</i> 1999;145:55-59.	OPERATIONS
3	Lessons from the first operational deployment of emergency medicine. <i>Journal of the Royal Army Medical Corps</i> 2000;146:134-142.	ORGANISATION
4	Training for major incidents: evaluation of perceived ability after exposure to a systematic approach. <i>Pre-hospital Immediate Care</i> 2000;4:11-16.	DOCTRINE
5	Incidence, location and reasons for avoidable in-hospital cardiac arrest in district general hospital. <i>Resuscitation</i> 2002;54:115-123.	ORGANISATION
6	The identification of risk factors for cardiac arrest and formulation of activation criteria to alert a medical emergency team. <i>Resuscitation</i> 2002;54:125-131.	ORGANISATION
7	Care of Civilians during Military operations. <i>International Journal of Disaster Medicine</i> 2005;3:3-24.	ORGANISATION
8	Evaluation of clinician attitudes to the implementation of novel haemostatics. <i>Journal of the Royal Army Medical Corps</i> 2005; 151:139-41.	TECHNOLOGY
9	ABC to <CABC>: redefining the military trauma paradigm. <i>Emergency Medicine Journal</i> 2006;23:745-746.	DOCTRINE
10	Battlefield Advanced Trauma Life Support (Part One). <i>Journal of the Royal Army Medical Corps</i> 2006: Suppl to volume 152(2). ...and (Part Two): Suppl to volume 152(3). ...and (Part Three): Suppl to volume 152(4).	DOCTRINE OPERATIONS
11	Trauma governance in the UK Defence Medical Services. <i>Journal of the Royal Army Medical Corps</i> 2007:153(4);239-242.	ORGANISATION
12	Operational Mortality of UK Service Personnel in Iraq and Afghanistan: A One-Year Analysis 2006-7. <i>Journal of the Royal Army Medical Corps</i> 2007;153(4):252-254.	ORGANISATION
13	Combat "Category A" calls: evaluating the pre-hospital timelines in a military trauma system. <i>Journal of the Royal Army Medical Corps</i> 2007;153(4):266-268.	OPERATIONS
14	Tourniquet use in combat trauma: UK military experience. <i>Journal of the Royal Army Medical Corps</i> 2007:153(4);310-313.	TECHNOLOGY
15	Damage Control Resuscitation. <i>Journal of the Royal Army Medical Corps</i> 2007:153(4);299-300.	DOCTRINE
16	UK Defence Medical Services guidance for use of recombinant Factor VIIa in the deployed military setting. <i>Journal Royal Army Medical Corps</i> 2007;153(4):307-9.	TECHNOLOGY
17	Benchmarking the UK military deployed trauma system. <i>Journal of the Royal Army Medical Corps</i> 2007;153(4):237-238.	OPERATIONS
18	Military Pre-Hospital Care: Why is it different? <i>Journal of the Royal Army Medical Corps</i> 2009;155(1):4-10.	DOCTRINE
19	The Joint Theatre Clinical Case Conference (JTCCC): Clinical governance in action. <i>Journal of the Royal Army Medical Corps</i> 2010:156(2);79-83.	OPERATIONS
20	The role of trauma scoring in developing trauma clinical governance in the Defence Medical Services. <i>Philosophical Transactions of the Royal Society B</i> 2011;366:171-191.	ORGANISATION

Table 2.1: Thesis Supporting Papers by Title and Theme

Table 2.2 identifies where each paper is referred to (by page number and section heading) throughout the text for ease of locating and assessing a specific paper.

Paper Number	Description Location Section headings followed by citations in text [page number]
1	5.3 [p74]
2	3.6 [p45] ◆ 4.6.2 [p59]
3	1.6 [p25] ◆ 4.2.1 [p51] ◆ 5.4.1 [p76]
4	3.5.3 [p43] ◆ 3.7 [p46]
5	4.6.4 [p62]
6	4.6.4 [p62]
7	5.3 [p74]
8	5.2 [p69]
9	3.2 [p37][p38] ◆ 3.6 [p45]
10	3.4 [p39]
11	2.1 [p28] ◆ 4.2.2 [p52]
12	4.4 [p55]
13	3.6 [p45] ◆ 4.6.2 [p59] ◆ 4.7 [p65]
14	3.3 [p38] ◆ 5.1 [p67]
15	3.5.1 [p41]
16	5.4.2 [p77]
17	1.4 [p22] ◆ 3.6 [p45] ◆ 7.1 [p91]
18	3.6 [p45]
19	4.3 [p54]
20	1.4 [p22] ◆ 1.6 [p25] ◆ 4.3 [p54] ◆ 4.6.1 [p58] ◆ 4.6.2 [p59]

Table 2.2: *Paper description locator by section heading and text citation*

2.5 Chapter summary

Part A has provided the purpose of the study to prove a Revolution in Military Medical Affairs (RM2A), the background to the proposed revolution and the methodology to be employed. 20 of my previously published peer-reviewed papers are offered as evidence, reinforced by reference to my additional publications including journal articles, books, book chapters and restricted internal reports.

Part B will consider the evidence, following the structured approach outlined, summarising in brief and critiquing each of the principal 20 papers.

PART B



THE EVIDENCE

INTENTIONALLY BLANK

3 Doctrinal revolution

“Theory cannot be accepted as conclusive when practice points the other way”

CHARLES CALWELL, 1906, p.70

3.1 Creating new approaches

At the heart of proving transformational change is the innovation in the concepts underpinning the practice of combat casualty care. As Calwell points out in the context of small wars, when theory and practice are in opposition then the theory needs to change (Calwell, 1990). This was the case with the established fundamental principles of resuscitation—‘ABC’, or ‘Airway, Breathing and Circulation’. Redefinition of the military trauma paradigm can be viewed retrospectively as the tipping point in transforming combat casualty care, the point after which major changes in training, practice and supporting technology were focused around the new priority principle of ‘Catastrophic haemorrhage’ (<C>). This was a doctrinal revolution.

3.2 ABC to <C>ABC

Paper 9 NEW CONCEPT	Hodgetts T, Mahoney P, Russell M, Byers M. ABC to <C>ABC: redefining the military trauma paradigm. <i>Emergency Medicine Journal</i> 2006a; 23: 745-6.
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“There is only one thing more difficult than getting a new idea into the military mind, and that is getting an old one out.”

Sir Basil Liddell Hart



ABC had become established since the 1980s as an irrevocable dogma, taught at every level of resuscitation from first-aider to hospital consultant, and reinforced through the national civilian training programmes of *Advanced Trauma Life Support* (American College of Surgeons, 2008) and *Advanced Life Support* (UK Resuscitation Council, 2008). Yet military experience was that ABC was counter-intuitive. For the soldier who has lost his legs to an improvised explosive device (IED), is conscious and is in severe pain, the highest priority is to immediately stop further bleeding—otherwise he will rapidly succumb to massive blood loss. What would appear

common sense was supported by Vietnam experience, which identified that haemorrhage from injured limbs was the most important cause of *avoidable* battlefield death (Champion *et al*, 2003).

In 2006 the British military followed my recommendations, broke with the civilian doctrinal standard and introduced the concept of <C>ABC (**Hodgetts** *et al*, 2006a; **Paper 9**), where <C> stands for 'catastrophic haemorrhage'. The strategist JFC Fuller called doctrine 'common sense...that is action adapted to circumstance' (British Army 2010), which chimes with the rationale for change. This should not, therefore, have been a surprise: it is actually a disappointment that it took so long to realise the lessons from previous conflict and to have the organisational courage to deviate from a civilian norm.

3.3 The Tourniquet Controversy

What was surprising was the internal resistance to this change, specifically from military orthopaedic surgeons who argued that tourniquets in the military setting were unsafe, contributed to morbidity (unnecessary limb loss) and had no effect on improving outcome (Parker *et al*, 2007). I defended the organisational position (**Hodgetts** *et al*, 2007b) and the body of subsequent international evidence has strongly confirmed the contribution of tourniquets to saving soldiers' lives (Brodie, **Hodgetts** *et al*, 2007; Kragh *et al* 2011). UK evidence (**Paper 14**) is discussed in Section 5, *Technology Revolution*.

Of strategic importance was that a superficially simplistic conceptual change had profound effects on the structure and content of all training programmes from individual first aid for every soldier (**Hodgetts** 2007f) through to collective pre-deployment training for the field hospital, and the enhancement in equipment at all levels of the evacuation chain.

The <C>ABC conceptual change alone can be argued to meet Lambeth's (1997) precepts of a revolution and fulfils Cohen's (2009) requirement to demonstrate a change in the processes of 'battle'. How I anchored this change through incorporation into pan-organisational clinical doctrine publications is described in Section 3.4. Importantly, <C>ABC was only one of a range of new concepts I introduced to support transformation: the wider concepts are described in Sections 3.5-7.

3.4 Anchoring doctrinal changes

Paper 10 NEW CONCEPTS	Hodgetts T, Mahoney P, Evans G, Brooks A (eds). Battlefield Advanced Trauma Life Support (Part One). <i>JR Army Med Corps</i> 2006c: Suppl to volume 152(2). ...and (Part Two): Suppl to volume 152(3). ...and (Part Three): Suppl to volume 152(4).
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Clinical doctrine, in the sense of ‘practice that is believed, understood and taught’ (British Army 2010), was codified in the 1980s within *Casualty Treatment Regimes* (CTRs—a field *aide memoire*) and the *Battlefield Advanced Trauma Life Support* (BATLS) course manual. CTRs fell out of use in the 1990s as they were not updated and therefore lacked enduring clinical validity. The BATLS course manual was regularly revised and the 2006 edition (**Hodgetts et al**, 2006b; reproduced as journal supplements 2006c-e, **Paper 10**) launched the <C>ABC and other resuscitation concepts. The principal conceptual changes in BATLS are shown in Table 3.1.

The introduction of <C>ABC coincided with a step change in how the BATLS course was delivered, recognising that the previous educational approach of ‘one size fits all’ did not match the ground truth. The manual emphasised the difference in approach throughout ‘4 Stages of Resuscitation’—Care Under Fire, Tactical Field Care, Field Resuscitation and Advanced Resuscitation. Further, it introduced the concepts of a truncated clinical assessment in a semi-permissive environment (the Tactical Rapid Primary Survey, TRaPs) and a standardised patient summary (the ‘MIST Message’—Mechanism, Injuries, Signs, Treatment). MIST has become anchored in broader military culture as it has been adopted within the NATO standardised message requesting casualty evacuation on operations.

However, a gap still existed to provide comprehensive guidance across the full scope of military medicine. In 2007, *Clinical Guidelines for Operations* (CGOs) were released, which used the <C>ABC concept as a common root and the start point for every emergency in medicine (**Hodgetts** 2007e). This was a further diversion from civilian practice, which compartmentalises how an emergency is approached in terms of trauma, cardiac, environmental, toxicology (poisons, including radiation and chemical agents) and paediatrics. Uniquely, the military concept of CGOs facilitates cross-boundary clinical problem solving: it was distributed by the Development

Concepts and Doctrine Centre (**Hodgetts** 2008a) and is supported by a process for regular updates.

Old BATLS Concepts (<2005)	New BATLS Concepts (≥2006)
ABC AIRWAY-BREATHING-CIRCULATION	<C>ABC CATASTROPHIC HAEMORRHAGE-AIRWAY-BREATHING-CIRCULATION ...and new equipment to support <C>ABC concept: - Elastic field dressing - Topical haemostatics - Commercial tourniquet 'Haemostasis Ladder' CONCEPT FOR STEPWISE USE OF NEW EQUIPMENT / TECHNIQUES: INTRODUCED AS CHANGE BETWEEN 2005 & 2008 EDITIONS
Single approach to resuscitation	4-stage resuscitation: - Care Under Fire (CUF) - Tactical Field Care (TFC) - Field Resuscitation - Advanced Resuscitation
Primary Survey	Tailored Primary Survey - CUF: assess <C>A only - TFC: Tactical Rapid Primary Survey - Field & Advanced Resuscitation: full Primary Survey
Casualty reporting: no standard	Casualty reporting: MIST message MIST HAS SUBSEQUENTLY BEEN INCORPORATED NOT ONLY INTO PATIENT HANDOVER AT SUCCESSIVE LEVELS OF CARE, BUT INTO STANDARD NATO 9-LINE REPORT TO REQUEST EVACUATION HELICOPTER AT SCENE
Crystalloid fluid resuscitation HARTMANN'S SOLUTION OR NORMAL SALINE	Early blood product resuscitation RED CELLS AND PLASMA (2008 REVISION OF MANUAL)
Hypotensive resuscitation FLUID JUST ENOUGH TO MAINTAIN RADIAL PULSE	'Novel hybrid' resuscitation FLUID JUST ENOUGH TO MAINTAIN RADIAL PULSE FOR FIRST HOUR THEN FLUID TO RESTORE NORMAL BLOOD PRESSURE
Cut-down as a technique of failure WHEN PERIPHERAL CANNULATION FAILS	Intraosseous as a technique of failure WHEN PERIPHERAL CANNULA FAILS OR 1 ST CHOICE IN CARDIAC ARREST
Common skills for all providers (doctors, nurses, medics)	Skills tailored for level of clinical competence

Table 3.1: *Principal conceptual changes in Battlefield Advanced Trauma Life Support*

3.5 Wider conceptual innovation in trauma

3.5.1 Damage Control Resuscitation

Paper 15 NEW CONCEPT	Hodgetts T, Mahoney P, Kirkman E, Midwinter M. Damage Control Resuscitation. <i>JR Army Med Corps</i> 2007c; 153(4): 299-300.
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Although the change to <C>ABC represents a paradigm shift in medical practice at all levels of provider, it is subordinate to the new concept of *Damage Control Resuscitation* (DCR) that Hodgetts *et al* (2007c, p.299) define as:

“A systemic approach to major trauma combining the <C>ABC (catastrophic bleeding, air way, breathing, circulation) paradigm with a series of clinical techniques from point of wounding to definitive treatment in order to minimise blood loss, maximise tissue oxygenation and optimise outcome.”

The purpose of introducing this concept was to draw together a series of innovations in equipment and practice into a coherent doctrine that would both assist in medical planning and introduce a more comprehensive ‘currency’ of acute trauma capability, be it for combat casualty care or civilian trauma. *Damage Control Surgery* (DCS, my emphasis) has emerged as ‘best practice’ for the critically injured patient from North American experience of civilian trauma (Moore *et al* 1998). The precepts of DCS are a trilogy of:

- A time-limited operation (primary surgery), recognising that the patient’s commonly deranged physiology (acidosis, coagulopathy, hypothermia) will not tolerate prolonged surgery;
- Intensive care to correct coagulopathy, hypovolemia [and related acidosis], and hypothermia—the ‘lethal triad’ (Blackbourne *et al* 2008);
- Secondary surgery when the patient’s physiology is stabilised.

DCR recognises that active measures to stop bleeding and treat coagulopathy are started in the pre-hospital setting in our military treatment model for critical injury. This potentially ameliorates the severity of physiological derangement previously encountered during primary surgery, extends the window of opportunity during primary surgery and reduces the challenge of the lethal triad on Intensive Care. Collectively, this would be expected to improve survival and evidence of this is

presented in Section 4, *Organisational Revolution*. DCR has been falsely interpreted by some planners to offer resource savings—just as DCS is a time-limited operation, it has been interpreted that DCR is a truncated resuscitation. In fact, the opposite is true as to deliver DCR requires a more sophisticated trauma system that can project technology to the point of wounding (tourniquets, haemostatic dressings—see Section 5, *Technology Revolution*) and provide blood products in the pre-hospital setting.

3.5.2 Haemostatic Resuscitation & Right Turn Resuscitation

Linked to the organisational consolidation of DCR as the guiding trauma resuscitation precept are the concepts of *Haemostatic Resuscitation* (Kirkman, Watts, **Hodgetts et al**, 2007) and *Right Turn Resuscitation* (Hettiaratchy, Tai, Mahoney, **Hodgetts** 2010). *Haemostatic Resuscitation* recognises the direct relationship between coagulopathy and mortality and defines a new optimum approach to blood product replacement therapy that more aggressively addresses coagulopathy. Again, this is more resource demanding as the central tenet is an increase in the use of plasma—with a change in the ratio of red cells to plasma transfused from 4:1 to 1:1.

Right Turn Resuscitation represents a reconfiguration of how teams work together at the field hospital in order to improve outcome—the critically injured are taken directly from the helicopter into the operating theatre, where Emergency Medicine, Surgery and Radiology teams conduct complex resuscitation in parallel. Conceptually, the change is from a 2-dimensional, vertical approach to surgical resuscitation to a 3-dimensional, horizontal and concurrent approach (**Hodgetts** 2011, unpublished: Figures 3.1-3.2). Further, it emphasises the precept that “Surgery does not follow resuscitation, it is part of resuscitation” (**Hodgetts**, Turner 2006f).

All of these conceptual innovations, translated into clinical doctrine, fulfil Lambeth’s criteria for revolution. In addition, by influencing equipment (diagnostic, monitoring, treatment) and the training and organisation of clinical teams, they are meeting the Toffler (1993) criteria for a ‘true revolution’.

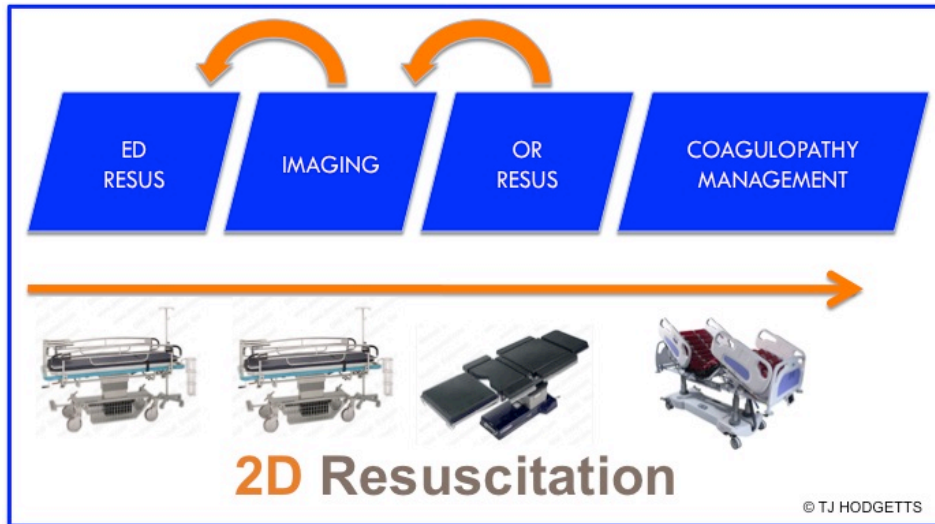


Figure 3.1: 2-D Resuscitation

[ED = Emergency Department; OR = Operating Room]

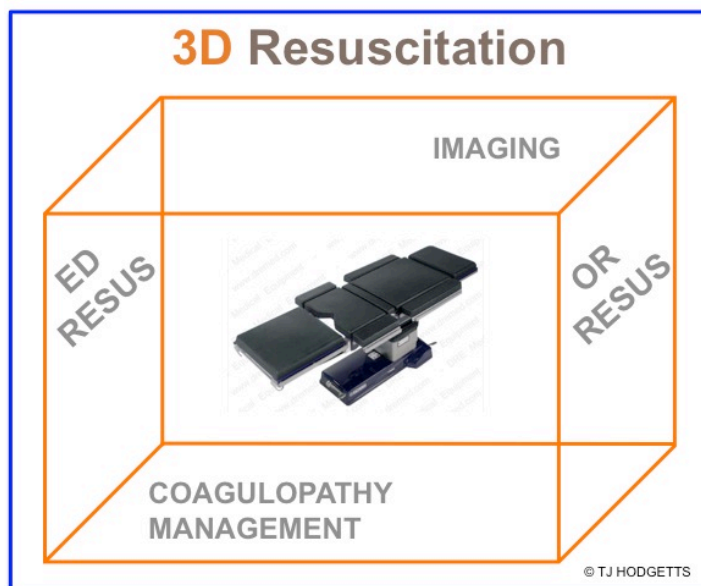


Figure 3.2: 3-D Resuscitation

[ED = Emergency Department; OR = Operating Room]

3.5.3 Trauma heuristics

New concepts can be communicated as heuristics—a ‘rule of thumb’ that acts as a mnemonic, and is presented as an acronym or memorable phrase. The development and propagation of a raft of heuristics in trauma, resuscitation, and disaster management has been a substantial contribution to conceptual innovation in this field (*Trauma Rules*, Hodgetts *et al* 1997 & 2006; *Resuscitation Rules*, Hodgetts and Castle 1999; *Disaster Rules*, Russell, Hodgetts *et al* 2010). This approach to

simplify complex situations in order to provide a framework to act has Clausewitzian⁵ origins:



“Everything in war is simple, but even the simplest thing is difficult.”

Clausewitz, *On War* (1832)

Nevertheless, Clausewitz highlighted that simple systems did not take account of *complexities* and what really matters is *experience* to make difficult decisions:



“Efforts were therefore made to equip the conduct of war with principles, rules or even systems. This did present a positive goal, but people failed to take adequate account of the endless complexities involved.”

“Only the experienced officer will make the right decision...at every pulse beat of war. Practice and experience dictate the answer.”

Clausewitz, *On War* (1832)

The counter-argument is that in a clinical crisis, where the NHS Trauma Team Leader is commonly inexperienced (NCEPOD 2007), it is the complexity itself that is paralysing. This is amplified in the unfamiliar setting of a ‘major incident’, given that most clinicians have no previous exposure and little or no structured training (Hodgetts 2000b—**Paper 4**, Section 3.7; Hodgetts 2003). Rules provide the initial framework around which medical commanders can improvise and the co-ordinating structure in extreme confusion around which professionals can rally. The difference with war is that *everything* is uncertain in war—but in a ‘simple’, ‘compensated’ major incident uncertainty can be relatively quickly transformed into certainty, and the emergency services can gain progressive control of the situation. The major incident response is effectively a unilateral action, rather than war’s characteristic continuous interaction of opposites.

⁵ Carl von Clausewitz was a 19th Century Prussian military strategist whose landmark treatise *On War* (1832) is still studied by contemporary Army Officers.

Nevertheless, personal experience of successive major incidents⁶ from 1988 to 2009 has resulted in a shift in mind-set from rigidly following a system to flexibly adapting the approach on each occasion—this is consistent with Clausewitz’s view of “military genius”, which relates to deep experience and intuition, and which “rises above all rules”. For the lesser experienced, a systematic approach is still endorsed.

3.6 Conceptual differences in military pre-hospital care

Paper 18 NEW CONCEPTS	Hodgetts T, Mahoney P. Military Pre-hospital Care: Why is it Different? <i>JR Army Med Corps</i> 2009; 155(1): 4-10.
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The importance of identifying conceptual differences in military versus civilian pre-hospital care lies with managing expectations of transferring excellent outcomes from the contemporary military operational environment to the civilian home base in the UK. A principal difference is that care is embedded at the point of wounding in the military (every soldier is taught and tested on first aid at least once annually—**Hodgetts** 1999, **Paper 2**) and treatment starts almost immediately: there is an inherent delay in the civilian setting to call an ambulance. Every soldier has their own equipment (dressing, tourniquet, morphine) and a minimum of 1 in 4 soldiers has advanced training and equipment—the average time for this ‘Team Medic’ to start treatment is currently 2 minutes after injury (**Hodgetts & Findlay**, 2012a).

Military trauma differs vastly in its mechanism (blast & ballistic > blunt) compared to civilian trauma and is statistically more severe, $p < 0.0001$ (**Hodgetts** 2007a, **Paper 17**). This influences the conceptual approach adopted (<C>ABC versus ABC, **Paper 9**) the shortened target timelines to initial surgery (McLeod & **Hodgetts** 2007h, **Paper 13**), and the paradigm of aggressive management of coagulopathy that starts in the pre-hospital setting.

Contemporary military pre-hospital care involves a physician-led team delivered by helicopter and providing advanced resuscitation in-flight: on scene times average only 2 minutes because of the hostile environment. The concept is therefore one of ‘scoop and play’, which is not seen in the civilian setting (‘scoop and run’ when there are limited skills or ‘stay and play’ with advanced interventions). This, combined with

⁶ Hospital Evacuations for terrorist bomb threats, Hannover 1998-9; IRA bombing of Musgrave Park Hospital 1991; operational experience in Kosovo, Oman, Kuwait, Iraq and Afghanistan 1999-2009 (war fighting and post-conflict).

direct admission to the operating theatre on arrival, supports the achievement of surgery within the ‘Golden Hour’ (Cowley 1976). While reduced time to surgery can be claimed to underpin the excellent outcomes it is harder to quantify the difference that an experienced pre-hospital doctor makes. **Paper 18 (Hodgetts and Mahoney, 2009)** summarises attempts to do this, recognising the limitation of self-reporting post-incident of value added, but quantifying the cases where a physician-only intervention was undertaken (anaesthesia; thoracotomy; ketamine or fentanyl analgesia) and procedures where physician judgment could influence whether there was a balance of benefit for skills to be undertaken (surgical airway, chest drain). 215/595 (36%) of cases fitted these criteria. This paper predates the widespread use of blood and plasma given by a physician on the helicopter, which is now a critical component in the early management of the coagulopathy of trauma (Kirkman *et al* 2007). Objective evidence for physician impact has been one of the organisation’s most pressing needs while working in an environment of multi-national pre-hospital care provision in Afghanistan, where different standards of pre-hospital care produce substantial friction.

3.7 Concepts for multiple casualty management

Paper 4 NEW CONCEPTS	Hodgetts T. Training for major incidents: evaluation of perceived ability after exposure to a systematic approach. <i>Pre-hospital Immediate Care</i> 2000c; 4: 11-16.
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Prior to 1992 there was no systematic approach to the management of multiple casualty incidents. The catalyst for developing this was the IRA bombing of the military wing of Musgrave Park Hospital, Belfast, on 2 November 1991. In the incident I acted as the Medical Commander, improvising a Casualty Clearing Station and coordinating the evacuation of in-patients and the treatment of the injured (Hodgetts 1993). This led directly to co-development of the Major Incident Medical Management and Support (MIMMS) programme in partnership with the Advanced Life Support Group in Manchester (Hodgetts and Mackway-Jones 1995a). The first MIMMS course ran in Manchester in 1993—within one year it had been internationalised and was established as a standard in Australia. It has subsequently been adopted widely in Europe (Sweden, Netherlands, Italy), Asia (India, Japan), the Middle East (Qatar) and South Africa. In 2004 the military version became the NATO standard. The core new concepts introduced are summarised in Table 3.2.

New Concept	Description / Comment
OVERARCHING CONCEPT 'CSCATTT': a simple, systematic approach that can be applied to any multiple casualty incident and has cross-boundary utility (national boundaries and the civil-military boundary)	Command, Safety, Communications, Assessment, Triage, Treatment and Transport
COMMAND 'Bronze-Silver-Gold' tiers of command	Adopted from Police, but not in use by health services prior to MIMMS
SAFETY '1-2-3 of Safety'	Prioritised safety of (1) Self, (2) the Scene and (3) the Survivors
COMMUNICATION 'METHANE' message	Major Incident Standby/Declared; Exact location; Hazards; Access; Number/severity of casualties; Emergency services present & required WAS 'ETHANE' IN 1ST EDITION; WIDELY ADOPTED BY UK MILITARY DURING OPERATIONS IN IRAQ
COMMUNICATION 'Cross of Communication'	Understanding of the horizontal communication/liason requirements
TRIAGE 'Triage Sieve'	A simple physiological system of triage for all providers USED FOR EVERY SOLDIER IN BRITISH ARMY FROM 1998; TAUGHT TO UK FIREFIGHTERS AND POLICE; INCREMENTAL CHANGE TO DEVELOP CHEMICAL TRIAGE AND PAEDIATRIC TRIAGE VARIANTS
TRIAGE 'Triage Sort'	A more sophisticated physiological system of triage for healthcare providers

Table 3.2: New Concepts Developed for the MIMMS Course

In addition to new concepts, MIMMS introduced individual skills to enhance performance at an incident (radio communications practice using the standardised METHANE format; practice on simulated casualties of both the Triage Sieve and the Triage Sort. Scene performance was further supported by a waterproof aide memoire (Hodgetts *et al* 1995b; Hodgetts and Porter 2002a).

Evaluation of perceived ability after attending the MIMMS course was undertaken by pre-course and post-course questionnaires, validated for content and designed to exclude response bias (Hodgetts 2000, Paper 4). There were 100% returns. Only 59% of candidates had received any pre-course training in disaster management, and only 25% of doctors with prior training agreed that it was adequate. 100% of candidates agreed post-course that MIMMS provided adequate training.

This was a small study (n=41 candidates questioned) and is illustrative. Greater reliability of the results could be obtained with a larger cohort. Statistical analysis to

determine the significance of attitudinal change (e.g. Fisher's Exact Test) would also add value even with a small sample. It is important to be able to validate an individual's perceived ability to perform in a disaster with their actual ability during a disaster and to map whether the principles and skills taught have genuine practical application. The unpredictability of disasters, their relative rarity and their global distribution have meant there is still no substantial educational research to prove this—rather, anecdote has reinforced taught practice or stimulated incremental change (e.g. serial modification of the Triage Sieve algorithm).

3.8 Chapter summary

This chapter has described a series of new concepts introduced over 10 years that contribute to the body of medical knowledge and have transformed combat casualty care practice. Collectively they have changed the 'rules of the game', requiring new doctrine, military tactics, and medical techniques to be developed.

In the next chapter attention is turned to how the Defence Medical Services has learned lessons from its deployments and reorganised to optimise the delivery of combat casualty care from point of injury to rehabilitation. Additionally, systems of information management are explored that have been developed to serially improve—and indeed transform—operational performance.

4. Organisational & Operational Revolution

4.1 Setting the conditions for transformation

If it is accepted that new concepts and doctrine have been introduced it needs to be determined whether these are because of, or in spite of, organisational restructuring and novel processes. Following the Strategic Defence Review in 1998 (SDR '98) there was substantial reorganisation of DMS management structures, with enhanced centralised co-ordination of single Service medical components under the Surgeon General (MOD 1998). Bernard Loo (2009) highlights the tendency to represent transformation as a top-down rather than a bottom-up process: it would be a convenient interpretation to causally link revised management structures to improved clinical outcomes—but this cannot be assumed. It demands supporting evidence, which can be drawn from the formation of the Royal Centre for Defence Medicine (RCDM).

The Centre for Defence Medicine [sic] was opened in 2001 in Birmingham, receiving its Royal Charter in 2002. At its theoretical inception within SDR '98 it was visualised to be a:

“...centre of excellence...for operational and battlefield medical research and advanced thinking...and...dedicated training of the highest quality.”

(HCDC 1999, p.xxiii)

Importantly, RCDM provided the infrastructure for military academic departments to develop. Central to driving the changes in concepts, doctrine, training, equipment and governance in combat casualty care described in this thesis has been the work of the Academic Department of Military Emergency Medicine (ADMEM) at RCDM. It is reasonable to deduce that without the formation of RCDM there would have been a less optimal environment for academic innovation and change would at best have been slower, but more realistically less comprehensive. So organisational restructuring can be claimed to be essential in supporting the clinical developments that have transformed performance. However, it would be false to claim central strategic direction for the academic innovations, which arose *de novo* within the departments in response to deep understanding (through repeated operational deployments) of the clinical-academics. In this sense, changes to training and clinical practice have been driven *middle-down*. Conversely, changes to equipment and policy have been informed from the *middle-up*, although have been progressively

driven from the top-down as both the intensity of casualties and the enduring nature of operations in Afghanistan have developed—and public, media and Ministerial attention has encouraged central direction.

Although RCDM was established as an *alma mater* for military clinical-academics it has evolved following war-fighting in Iraq in 2003 to be the principal receiving hospital for UK operational casualties. This has created opportunity for further management restructuring, with Defence recognition of the military ‘Role 4’ concept (that is, the need for a military framework of support within the NHS hospital designated for definitive care, linked with seamless continuity of care for those discharged to a military rehabilitation facility)⁷ co-ordinated by a Standing Joint Commander Medical. Porter (2012) describes the transformation of Role 4 in detail, to include changes in military manpower, clinical capacity to handle ventilated casualties, process change to accommodate increased operating theatre requirements, and an improved multidisciplinary management approach to complex cases. In addition, SDR '98 stimulated an enhancement of the Army's ambulance evacuation capability and created an additional 800 Field Hospital beds. Collectively, the structural changes to the organisation satisfy Cohen's (2009) first rule of revolutionary change—that the forces must look fundamentally different.

4.2 Information as a performance-transforming enabler

The co-location of the military academic and operational casualty treatment components in Birmingham has also facilitated the development of a comprehensive clinical information management system to transform quality assurance. Descriptions of a traditional RMA focus on the information revolution. Lawrence Freedman (1998) postulates that information dominance is at the heart of the contemporary revolution, with the emphasis on gathering, processing and near-real time distribution to commanders. He notes that human judgement may be necessary, which incurs a time penalty. Further, he recognises that high quality information does not guarantee high quality interpretation, nor does high quality interpretation guarantee high quality decisions. How then do these observations on information management in the *non-medical* military operational context relate to how an information revolution can transform *clinical* performance?

⁷ The military medical Roles are defined at Annex B.

The simple answer is that the principles of information management are generic. Prior to 1997 the DMS did not collect data that allowed a comparison of trauma system performance: the aim of DMS was to provide ‘as near NHS best practice as achievable within operational constraints’, with the inherent assumption that deployed care fell below the standard of NHS care.

4.2.1 The Military Trauma Registry: first steps

Paper 3	Hodgetts T, Kenward G, Masud S.
ORGANISATION (GOVERNANCE)	Lessons from the first operational deployment of emergency medicine. <i>JR Army Med Corps</i> 2000a; 146: 134-42.

In 1997 I established a trauma registry in Frimley Park Hospital, a combined NHS and military hospital, following an Australian model. The aim was to improve the holistic care of all seriously injured patients presenting to the hospital. This model was transposed to the British field hospital in Kosovo in 1999 (**Hodgetts et al**, 1999; **Hodgetts et al** 2000a, **Paper 3**) and a direct comparison was made retrospectively of NHS versus DMS system performance using recognised international models (Wesson’s criteria). Performance was effectively the same in both environments (Table 4.1), with some improved indicators in the field hospital (seniority within the trauma team; time to surgery) and some impaired indicators in the field (time to CT). Importantly, performance in the civilian hospital was shown to dip in the period that continuous audit and governance were suspended while trauma audit staff were in Kosovo (**Hodgetts et al** 2000b): the dip was from a peak annual system performance of 85.3% judged by Wesson’s criteria (1998-1999) to 68.0% coinciding with the suspension of audit (1999-2000).

Wesson’s Criteria	
This is salvageable major trauma patients who survived [SS] ÷ salvageable patients who survived & died [SS +SD] x 100	
That is: [SS] ÷ [SS + SD] x 100	
A salvageable major trauma patient is one with ISS 16-59	
Kosovo Field Hospital, 1999:	84.6%
Frimley Park Hospital, 1998-1999:	85.3%
Notes: Frimley Park Hospital performance dipped to 68.0% during 1999-2000 while military audit staff were in Kosovo. A ‘major trauma’ patient is defined as having an Injury Severity Score (ISS) ≥16.	

Table 4.1: Comparative Performance of a Field Hospital and an NHS Hospital

The importance of **Paper 3** is that it was the first published objective evidence of modern military trauma system effectiveness; it established the benchmark that military operational care was at least as good as NHS care for major trauma; and it set the standard for all subsequent data collection during the Iraq (2003-2009) and Afghanistan (2001-date) conflicts, raising the expectations for detailed analysis of system performance. Further, it highlighted the limitations of civilian-oriented trauma scoring systems, with the requirement to capture the 'New' Injury Severity Score (Osler *et al* 1997) alongside the traditional Injury Severity Score if prediction of mortality (and therefore prediction of system performance) was to be truly representative. Perhaps most importantly, as the first operational deployment of Emergency Medicine as a specialty its role and reputation was sharply established and the conditions were set to lead transformational change in doctrine, training and equipment. This was the true birth of the combat casualty care revolution and the catalyst for a decade of sustained change.



Figure 4.1: *Kosovo Field Hospital—the catalyst for revolution*

[Colonel Hodgetts in centre]

4.2.2 Refining the Military Trauma Registry

The military's trauma audit programme was transferred to Birmingham on establishment of RCDM in summer 2001. The events of '9-11' later that year set the conditions for two major conflicts in Iraq and Afghanistan and a new focus on Birmingham to provide the definitive treatment to the war injured: this directly led to the development of the scope and sophistication of the trauma registry, which was

matched with supporting human resources as the organisation's dependence on the output has grown (a dependence, that is, to prove clinical effectiveness and provide reliable epidemiology in the public interest). To reflect the sources of injured patient data from all UK expeditionary operational areas since 2003, it was renamed the *Joint Theatre Trauma Registry* (JTTR).

Paper 11	Smith J, Hodgetts T, Mahoney P, Russell R, Davies S et al.
ORGANISATION	Trauma governance in the UK Defence Medical Services.
(GOVERNANCE)	<i>JR Army Med Corps</i> 2007; 153(4): 239-42.

JTTR is fundamentally a quality assurance system designed to detect unexpected outcomes (unexpected survivors, unexpected deaths, complications, emerging new injury patterns and adverse events) in order to maintain and develop standards of care (Smith, Hodgetts *et al* 2007, **Paper 11**). A team of Trauma Nurse Co-ordinators collects detailed prescribed information during resuscitation, surgery and intensive care in the field hospital; this is collated with the patient's pre-hospital record and interventions and outcomes from their continuing Role 4 care⁸ in UK. Compliance with pre-determined key performance indicators (KPIs) allows system weaknesses to be identified, remedial education to be put in place and the impact on improved performance to be measured—this is the MACE Cycle (*Major Trauma Audit for Clinical Effectiveness*, Figure 4.2).

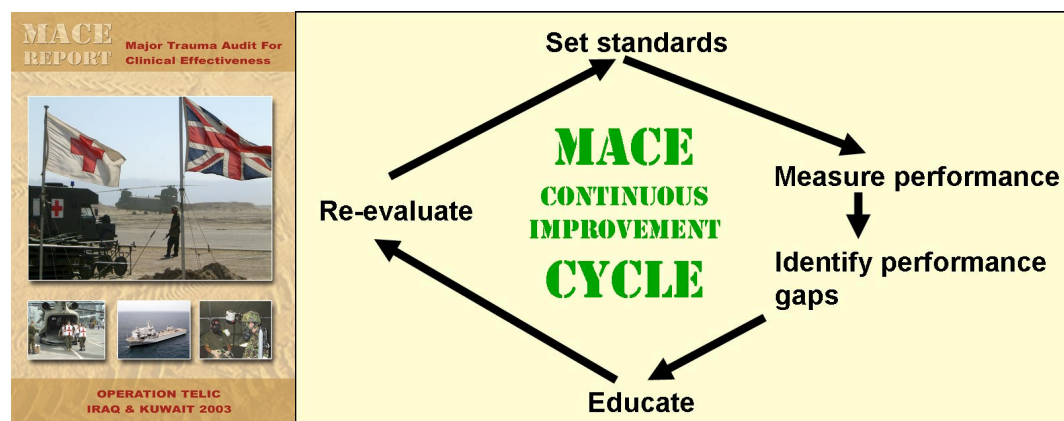


Figure 4.2: *The MACE Cycle and a MACE Operational Report*

The scope and depth of the continuous audit has been unmatched in UK civilian practice: in 2000 it was praised by the Commission for Health Improvement as an example of best practice (Hodgetts *et al* 2000a) and again in 2009 by its successor,

⁸ The military medical Roles are defined at Annex B.

the Healthcare Commission (HCC, 2009). JTTR is not designed as an electronic health record or a patient tracking system, although there are features of both these functions—organisational expectations have had to be managed when these functions have been demanded. A serendipitous benefit has been the ability to link patterns of injury with both the protective clothing worn and the seating position in a vehicle: this has identified specific vulnerabilities to be actively pursued within the Defence research and development programme (see Section 4.5).

4.3 Formalising and systematising clinical feedback

Paper 19	Willdridge D, Hodgetts T, Mahoney P, Jarvis L.
OPERATIONS (FEEDBACK)	The Joint Theatre Clinical Case Conference: clinical governance in action. <i>J Roy Army Med Corps</i> 2010; 156(2): 79-83.

Critical patient safety events in the deployed setting will now prompt remedial action through the chain of command within 24 hours. Otherwise, the principal driver for clinical change is the near-real time feedback provided during a weekly telephone conference. I established this *Joint Theatre Clinical Case Conference (JTCCC)* while in Afghanistan in 2007; subsequently, JTCCC has been chaired and strictly controlled through RCDM.⁹



Figure 4.3: JTCCC in progress in a field hospital (Afghanistan 2007)

[Colonel Hodgetts in centre]

⁹ I chaired JTCCC and managed the associated change continuously for the first 2 years.

JTCCC involves every stakeholder in the care pathway from primary retrieval through to rehabilitation with over-watch by the Surgeon General's Department (SGD) and Permanent Joint Headquarters (PJHQ). This inclusivity encourages high quality interpretation and consensus clinical decision-making by the subject matter experts, tested against policy and operational realities by the SGD and PJHQ. In an analysis of JTCCC effectiveness over 14 months, a wide range of clinical and non-clinical (equipment, policy, training) issues were identified with 68% (109/160) resolved within 3 weeks—training gaps were particularly rapidly addressed, with all issues closed within 3 weeks. JTCCC has become one of the main assets in progressively improving outcome, which is consistent with the independent analysis of the major trauma audit process rated by the Healthcare Commission as 'excellent' (HCC 2009). This supports Cohen's (2009) second criterion for evidence of revolutionary change—a demonstrable difference in the processes of 'battle'.

Criticisms of JTCCC have been its exclusivity to tracking progress of UK casualties (only half of the activity of the field hospital) and its exclusivity to trauma. Combat injuries have emotional currency with politicians and the public, but they are only a portion of the total patients evacuated from an operational setting—other patients are collectively identified as "disease or non-battle injury" (DNBI). The same depth of audit has not been undertaken for disease (although any serious non-battle injury is still audited), as 'disease' has lacked the clinical championship of a physician to establish and manage this process. However, outline epidemiology has been achievable after I introduced and led development of the increasingly sophisticated Operational Emergency Department Attendance Register, with continuous data collection from the 2003 Iraq conflict onwards (Russell, **Hodgetts et al** 2007; Russell, **Hodgetts et al** 2011, **Paper 20**; Ollerton, **Hodgetts et al** 2007; Ollerton and **Hodgetts** 2010).

4.4 A new framework of peer review

The development of human judgement that Freedman (1998) refers to in his analysis of the components of an RMA is particularly pertinent to the peer review panels established at RCDM to evaluate the number and reasons for unexpected survival, and to analyse every operational trauma death. These panels give the organisation a level of scrutiny and systemic rigour that is unmatched by civilian comparator institutions. To determine why is to begin to understand the differences in culture and organisation between the NHS and the DMS.

Military clinicians are conditioned differently. They are bonded morally by a common purpose to treat soldiers and psychologically by shared intense experiences (a shared threat to their lives, and shared clinical horrors). When coupled with the physical requirement on operations to live together in a confined space this generally makes the clinicians pull as a single team. This culture continues in the academic environment, enhanced by the juxtaposition of all the Defence Professors. It stimulates daily cross-boundary academic interaction, which is unusual within a university framework.

Paper 12	Hodgetts T, Davies S, Midwinter M, Russell R, Smith J et al.
ORGANISATION (GOVERNANCE)	Operational mortality of UK Service personnel in Iraq and Afghanistan: a one-year analysis 2006-7. <i>JR Army Med Corps</i> 2007d; 153(4): 252-4.

Academic analysis of every operational death has been undertaken since 2004, with systematic peer review since 2006 (**Hodgetts et al** 2007d, **Paper 12**). The panel is multidisciplinary and the principal objective is to codify casualties as ‘salvageable/non-salvageable’ (the likelihood that surgical intervention would be attempted and the predicted influence on survival) and ‘preventable/unpreventable’ (the likelihood that intervention was possible given the tactical circumstances and resources). This provides a continuous organisational barometer of performance and alerts the command chain to any unexpected death, coupled with an analysis of the reasons. This is a more sensitive indicator of system performance than the crude historical ratio of ‘Killed In Action’ to ‘Died of Wounds’, which can misinterpret an improved survival to hospital of non-salvageable injury as poor hospital care.

Further, the analysis demonstrates differences in injury patterns between both contemporary and historical conflict environments. For example, a higher incidence of hostile action death due to blast and fragmentation in Iraq vs Afghanistan (76% vs 57%) and more gunshot wound (GSW) deaths in Afghanistan vs Iraq (43% vs 24%)—yet the historical dominance of sepsis deaths from WW2 was not seen. The importance is to retain the ability to rapidly recognise these differences and to be flexible to adapt campaign-specific solutions to prevention (tactics and protective equipment) and treatment (novel clinical approaches).

The National Audit Office independently verified that there are a very small number of deaths that are considered avoidable on contemporary operations (NAO 2010). Nevertheless, as an early ‘adverse weather warning’ and quality assurance safety net an experienced clinician attends every military post mortem. This has been valuable in identifying sub-optimal practice, such as non-therapeutic placement of a drain or infusion device, and has regularly prompted immediate remedial action to amend training, policy or procurement direction.¹⁰ It is a clearly transferable practice to a civilian trauma system.

4.5 New relationships to stimulate capability development

A strong relationship with industry, developed in this decade of change, has assured both flexibility and willingness to rapidly adapt to trends in product malfunction, an example being the introduction of successive generations of the *FAST-1*® sternal intraosseous device (used to give drugs and fluid into the breastbone when no other site is available; Cooper, **Hodgetts et al** 2007).

An equally important and operationally sensitive relationship that has developed serendipitously is the joint development of personal and vehicle protective solutions using the detailed injury and survival data maintained by RCDM, and the expertise of the Defence Science and Technology Laboratory (Dstl [sic]). JTTR is a key source for Dstl’s continued development of protection within the *Dismounted Close Combat* and *PARSIFAL* (accelerated armour protection) programmes, which have been credited with saving soldiers’ lives in Afghanistan and Iraq (Dstl 2010). It was, for example, analysis of JTTR data in 2009 (my analysis while deployed) that identified the trend of genital injuries in current operations, which directly led to the development of protection by Dstl and the introduction of the “combat codpiece” in 2010 (Wyatt 2011). The argument is strong, therefore, that systems of information management and continuous detailed audit of combat deaths and injuries have transformed Defence’s ability to respond in an agile, evidence-based way to manage future Force Protection risk.

¹⁰ This assertion is verifiable by grey literature (internal reports derived from *sub judice* post mortem data, managed by the author 2004-2010).

4.6 Has system modernisation improved outcome?

4.6.1 Unexpected survivors

Paper 20	Russell R, Hodgetts T, McLeod J, Starkey K, Mahoney P et al.
ORGANISATION (GOVERNANCE)	The role of trauma scoring in developing trauma clinical governance in the Defence Medical Services. <i>Phil Trans Royal Society B</i> 2011; 366(1562): 171-91.

The analysis of unexpected survivors is the principal quantifiable evidence of remarkable system performance and, by deduction, evidence that performance has significantly improved (Russell, **Hodgetts et al** 2011, **Paper 20**). Further, by second order deduction, it is evidence that the change constitutes an RM2A because it is this evidence that satisfies Cohen's (2009) third criterion: that outcome is transformed.

Paper 20 is an analysis of 2 year's outcome (2006-8) from severe injury on expeditionary operations. A combination of internationally validated mathematical modelling is used (Table 4.2) tempered through independent case review by an expert panel. This composite approach balanced by clinical judgement is necessary because of weaknesses of individual mathematical models when relied on in isolation. The Injury Severity Score (ISS), for example, will consistently *under-represent* the *severity* of military blast trauma as only one amputated limb can contribute to the score, irrespective of whether the patient has multiple amputations. This weakness is transferred into TRISS (a combination of ISS and the Revised Trauma Score), thereby *over-estimating* the *probability of survival*. The New Injury Severity Score (NISS) allows for multiple injuries in the same body region and is therefore preferred in the military context—both scores are calculated as it is important to compare like for like when a military system is compared with a civilian system, even if the model is flawed.

	Trauma scoring model	Measure
1	ISS (Injury Severity Score)	Greater than or equal to 60
2	NISS (New Injury Severity Score)	Greater than or equal to 60
3	TRISS (probability of survival, Ps)	Less than 50%
4	ASCOT (probability of death, Pd)	Greater than or equal to 50%
5	Cardiac arrest	Documented cardiopulmonary resuscitation (CPR)

Table 4.2: *Mathematical Models to Determine 'Unexpected Survivors'*

75 cases were characterised as unexpected survivors, which represents 25% of all seriously injured survivors; in comparison, the rate of unexpected survivors in NHS hospitals achieved a maximum of 6% over a similar period of 2006-9 (National Audit Office 2010). 44 patients were "mathematical unexpected survivors" and 34 of these were validated by peer review. The additional 41 cases were identified as "clinical unexpected survivors": of this group, 36/41 (88%) had their outcome attributed to the advanced resuscitation strategies in the military to arrest and treat catastrophic haemorrhage following combat trauma. The 41 'clinical' cases were subcategorised as 26 "civilian unexpected, but military expected" and 15 "civilian and military unexpected": this allowed the expert panel to further differentiate those cases that would be expected to die in both environments from those expected to survive in a field setting but to die in the NHS, where the military advances were as yet poorly adopted.

4.6.2 Trauma cardiac arrest survivors

In a subset analysis, survival following cardiac arrest as a result of trauma was 24% in the military deployed trauma system (**Paper 20**). This is more than 3 times greater than the best recorded survival to hospital discharge in UK civilian practice—7.5% in over 10 consecutive years with the London Helicopter Emergency Medical Service (HEMS; Lockey *et al* 2006). Of relevance, survival in the London HEMS series remained very low for hypovolaemic arrest (blood loss), which was the principal underlying factor within the military cohort.

Paper 2	Hodgetts T, Hanlan C, Newey C.
OPERATIONS	Battlefield First Aid: a simple, systematic approach for every soldier.
(1ST AID)	<i>JR Army Med Corps</i> 1999a; 145: 55-59.

Traumatic cardiac arrest survival in itself represents a *volte-face* in military thinking and clinical doctrine, and an exceptional outcome: it screams a revolutionary change to achieve this. In 1999, a new system of individual first aid was brought into the Army, 'Individual Training Directive (Army) Number 3' (**Hodgetts et al** 1999a, **Paper 2**). This replaced lecture-based teaching with solely practical teaching; replaced assessment by multiple-choice questions with practical skills and scenario-based testing; and provided a simple, systematic set of generic first aid drills within a pocket *aide memoire*, *Battlefield First Aid Drills* (**Hodgetts** 1999b). In educational terms, this was a completely novel approach to first aid. Bravely, it extrapolated the heroic but

futile civilian experience from traumatic cardiac arrest (where meta-analysis demonstrated a survival approaching 0%—Boyd *et al* 1992) to the hostile environment of the battlefield: the deduction was there was no place for cardio-pulmonary resuscitation (CPR) on the battlefield, as all that would be achieved would be a ‘change in the geographical site of death’ while placing rescuers at considerable risk.

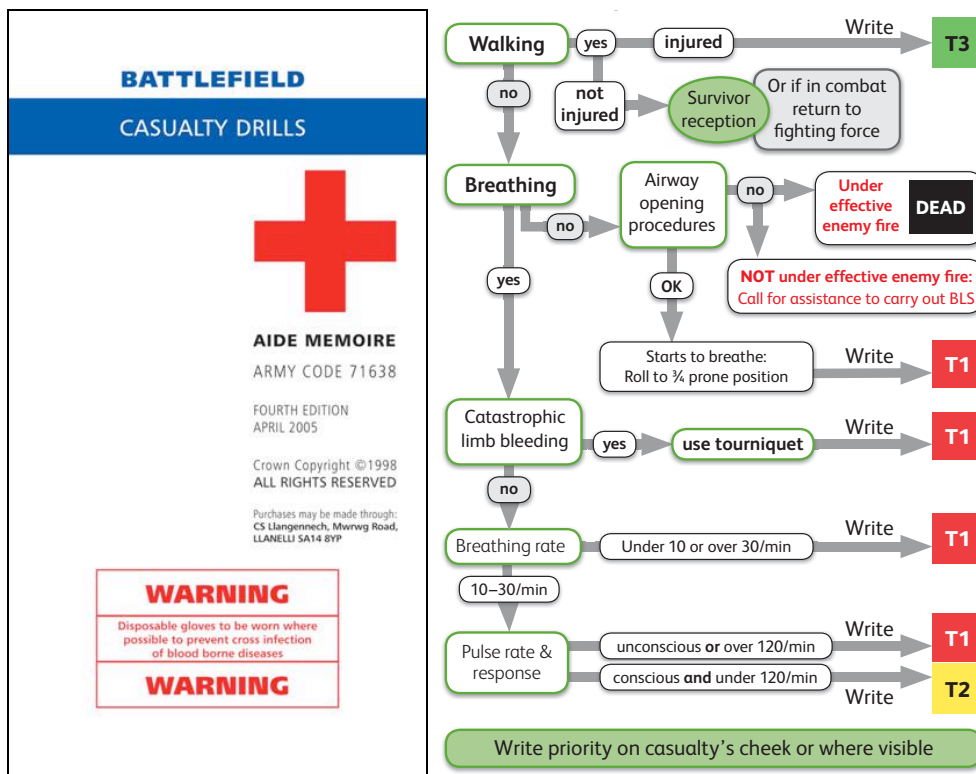


Figure 4.4: Battlefield Casualty Drills and Triage Sieve Incorporating CPR
 [CPR on this algorithm is synonymous with BLS, Basic Life Support] [4th edition cover shown, 2005]

In parallel, argument was made to retain CPR as a skill for the UK home base and peacekeeping operations, to contribute to the capability to deal with sudden cardiac death in the community. However, it was not until the 3rd edition of the *aide memoire* in 2004 that revised guidance was given for ‘troops in contact’, re-instating CPR as a skill in the combat environment (Hodgetts 2004a).¹¹ The step change in outcome is linked to when CPR is coupled with advanced interventions by a consultant-led and helicopter-borne resuscitation team (the *Medical Emergency Response Team*, MERT), which was introduced in Afghanistan from 2006 (Davis *et al* 2007).

¹¹ *Battlefield First Aid* was re-named *Battlefield Casualty Drills* on launch of the 3rd edition.

When the MERT team can intervene immediately following an arrest with advanced procedures (drugs, airway and surgical skills, blood transfusion) there is a small window of opportunity; benefits are also realised for those that arrest at the field hospital and receive immediate advanced intervention. It would be misleading to believe those who arrest on the battlefield and receive extended CPR from a buddy have a 24% chance of survival. They do not. It is the early access to CPR *and* advanced resuscitation that counts, which is compellingly coupled to the observed serially reducing clinical timeline from wounding to emergency surgery (McLeod, **Hodgetts et al 2007h, Paper 13**; see Section 4.7)—a postulated result of both process improvement and geographical contraction of the Area of Operation.

4.6.3 Cardiac arrest prevention: out of hospital

Where the difference *is* made at the point of wounding is the ability to sustain a patient and avoid cardiac arrest prior to the arrival of specialist medical support. This has, as described, involved doctrinal change through the concept of <C>ABC, an improved systematic approach to first aid and a rigorous audit and feedback system that monitors performance and adjusts practice accordingly. What has not yet been factored is the addition of a layer of *advanced first aid* capability in 2006, specifically designed to increase the chance of survival from massive haemorrhage. This is the Army Team Medic. At its inception the intent was to train 1:4 combat soldiers against an *aide memoire* (**Hodgetts 2008b**) that builds on the principles and skills within *Battlefield Casualty Drills*. The perceived success is now so high that military commanders demand a minimum of 1:2 trained to this level for contemporary operations, with the stated aspiration that all soldiers should be Team Medics. The doctrinal rationale is to supplement the life-saving interventions possible within the 'Platinum Ten Minutes' of opportunity, thereby sustaining life until specialist medical support is available within the 'Golden Hour' (Cowley 1976).

The Army Team Medic has been the far forward focus for introduction of new medicated bandage technology to stop bleeding from wounds that are not amenable to a tourniquet; in parallel, novel methods of training have been devised that use out of date blood products to activate these 'haemostatic dressings' in a realistic model (Moorhouse *et al* 2007). An innovation in capability level has therefore exploited innovation in technology and stimulated innovation in training. This has changed the shape of first aid provision on the battlefield, specifically altering the equipment, team organisation and doctrine of battlefield first aid—the Toffler (1993) criteria for a 'true revolution'.

4.6.4 Cardiac arrest prevention: in hospital

Paper 5 ORGANISATION (SYSTEMS)	Hodgetts T, Kenward G, Vlachonicholis I, Payne S, Castle N et al. Incidence, location and reasons for avoidable in-hospital cardiac arrest in a district general hospital. <i>Resuscitation</i> 2002b; 54 : 115-123.
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Despite the exceptional success of traumatic cardiac arrest resuscitation in the pre-hospital operational environment and the introduction of the Team Medic capability to potentially prevent arrest through early and effective intervention, there remains a spectre of avoidable *in-hospital* cardiac arrest. This was quantified for a UK hospital in 2002 (**Hodgetts et al 2002b, Paper 5**) when a staggering 68% of arrests were found to be avoidable by expert panel analysis. Extrapolating to the NHS gave a crude estimate of 23,000 avoidable deaths per year nationwide. The importance of prevention is the universally poor outcome at one year following in-hospital arrest, averaging 15% (Gwinnutt 2000).

Principal risk factors for avoidable arrest were admission to a general ward rather than a critical care area (Odds Ratio 5.1; 95% CI 2.2, 11.9; $P < 0.001$), or admission to an inappropriate area (Odds Ratio 12.6; 95% CI 1.6, 97.7). Avoidable cardiac arrests were more likely at weekends than weekdays ($P < 0.02$). Clinical signs of deterioration in the preceding 24 hours were not acted upon in 48%, with review confined to a House Officer (modern equivalent is Foundation Year 1) in 45%—understandably, in 100% of avoidable cases treatment leading up to the arrest was judged to be inadequate.

What is disappointing is that the NHS has demonstrated its failure to learn organisationally. 10 years after these findings the research company *Dr Foster* has reported a worrying 10% spike in deaths at weekends compared with weekdays across 147 NHS Hospital Trusts (Dr Foster 2012) and has noted that those hospitals with the fewest senior doctors available at the weekend have the highest mortality. This is reinforced by the NCEPOD report 'Time to Intervene' (NCEPOD 2012), stated by the Chair of NCEPOD to be 'the most important report NCEPOD has produced in the last 10 years' (p5) and that it was 'thoroughly dispiriting to find that...if the patient had been managed as they should have been...the arrest would not have occurred in the majority of cases. This is bad medicine...' (p6).

What is worse than the NHS ignoring the reasons for avoidable death (**Paper 5**), is failure to adopt the solution provided (**Hodgetts et al 2002c, Paper 6**) having been given the tools to do so—a nationally distributed DVD training package provided free to all hospital Resuscitation Officers (**Hodgetts and Kenward 2004**). The reasons why the NHS struggles to adopt innovation are discussed in Part D, *The Way Forward*. Understanding the barriers to innovation adoption is important if organisational learning from contemporary combat casualty care experience is to be effectively transferred (Box 4.1).

BARRIERS TO ADOPTION: MEDICAL EMERGENCY TEAM

Having gathered the evidence for avoidable cardiac arrest at Frimley Park Hospital, the change programme to fully implement the Medical Emergency Team solution across the Trust took approximately 1 year and the resources of a full-time project nurse. In parallel, during a field hospital deployment to Oman in 2001 (Exercise Saif Sarrea II) the solution was introduced over 48 hours. The differences are principally those of culture and directed change: when change is ordered in a military environment it happens, but every consultant within an NHS hospital is a potential focus of resistance that can stall or derail a change process.

Box 4.1: *Barriers to Adoption of Innovation—NHS vs DMS*

Paper 6	Hodgetts T, Kenward G, Vlachonicholis I, Payne S, Castle N.
ORGANISATION (SYSTEMS)	The identification of risk factors for cardiac arrest and formulation of activation criteria to alert a medical emergency team. <i>Resuscitation 2002c; 54: 125-131.</i>

The solution to preventing avoidable in-hospital cardiac arrest is a Medical Emergency Team (MET) activated on evidence-based criteria (**Paper 6**, Figure 4.5) and following standardised best practice guidelines. Activating the MET alone was not enough when the treatment by doctors was shown to be consistently inadequate. A set of guidelines with a novel, intuitive, symptom based structure was devised to cover all those conditions that had been demonstrated to underpin the avoidable arrests (**Hodgetts et al 2002d**): these proved to be an important conceptual precursor to *Clinical Guidelines for Operations* (**Hodgetts 2007e**).

Although antecedents of cardiac arrest were known to be common and empirical systems for triggering MET response had been developed (Hourihan *et al* 1995), this was the first time risk factors had been quantified and structured into a weighted response (Figure 4.6). A series of criteria were identified as significant predictors of cardiac arrest when compared with non-arrest controls. These included abnormal pulse ($P<0.001$), reduced systolic blood pressure ($P<0.001$), abnormal temperature ($P<0.001$), reduced pulse oximetry ($P<0.001$), and chest pain ($P<0.001$). Logistic regression identified three significant independent associations with cardiac arrest: abnormal breathing indicator (abnormal rate or a symptom of shortness of breath) (OR 3.49; 95% CI 1.69-7.21); abnormal pulse (OR 4.07; 95% CI 2.0-8.31) and reduced systolic blood pressure (OR 19.92; 95% CI 9.48-41.84).

NEW symptoms	4	3	2	1	0	1	2	3	4
Nurse concerned			NEW		NORMAL RANGE				
Chest pain		NEW							
AAA pain		NEW							
SOB		NEW							
Physiology									
Pulse changes	<45	45–49	50–54	55–60		90–99	100–119	120–139	>139
Temp-core (rectal/tympanic)	<34	34.0–34.5	34.6–35.0	35.1–35.9			38.5–39.9	40.0–40.4	>40.4
RR (adult)	<8	8–9	10–11			21–25	26–30	31–36	>36
SpO ₂ (O ₂)	<88	88–91	92–95						
SpO ₂ (Air)	<85	86–89	90–93	94–96					
SBP (mmHg)	falls to <90	falls to 90–99	falls to 100–110			rises by 20–29	rises by 30–40	rises by >40	
or	falls >40	falls by 31–40	falls by 20–30			Pulse pressure narrows 10	Pulse pressure narrows >10		
GCS changes	<13		13–14				confused or agitated		
Urine output	<10mls/hr for 2 hours	<20mls/hr for 2 hours					>250mls/hr		
Biochemistry									
K ⁺		<2.5	2.5–3.0				5.6–5.9	6.0–6.2	>6.2
Na ⁺	<120	120–125	126–129			146–147	148–152	153–160	>160
pH	<7.21	7.21–7.25	7.26–7.30	7.31–7.34		7.46–7.48	7.49–7.50	7.51–7.60	>7.60
pCO ₂ (acute changes)		<3.5	3.5–3.9	4.0–4.4				6.1–6.9	>6.9
SBE	<-5.9	-4.9 to -5.8	-3.8 to -4.8	-3 to -3.7					
pO ₂ (acute changes)	<9.0	9.0–9.4	9.5–9.9	10–11					
Creatinine					121–170	171–299	300–440	>440	
Hb	<80	80–89	90–100						
Urea			<2	2.0–2.4	7.6–20	21–30	31–40	>40	

Figure 4.5: MET Evidence-based Activation Criteria

The importance of the ‘breathing indicator’ resonated strongly with the finding that basic nursing observations were omitted or not acted upon (**Paper 5**)—what was necessary was an educational campaign to ‘Put the R back into TPR’ (Kenward and

Hodgetts 2001). The lack of NHS organisational learning in the following ten years was evident in 2011 when the Chief Executive and General Secretary of the Royal College of Nursing admitted that the lack of basic care skills for new nurses was nothing short of a disgrace (Public Service 2011).

Score	Action
1	Observe
2–3	Repeat TPR, BP, GCS, calculate urine output last 2 hours (if known) Now recalculate score (if same, observe closely)
4	Bleep patient’s SHO (to attend within 30 minutes)
5–7	Confirm with Senior Nurse then 333 SHO of patient’s speciality
8 or more	Inform Senior Nurse then
Activate MET	

Figure 4.6: MET Weighted Response

For the combat environment at least, in-hospital cardiac arrest prevention training is now institutionalised within a field hospital’s preparation for deployment, so the system stays active on every turnover of staff each 3 months irrespective of the parent NHS hospital from which regular and reserve personnel are drawn.

4.7 Have shortened timelines improved outcome?

Paper 13 OPERATIONS (TIMELINES)	McLeod J, Hodgetts T, Mahoney P. Combat “Category A” calls: evaluating the pre-hospital timelines in a military trauma system. <i>JR Army Med Corps</i> 2007h; 153(4): 266-268.
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Survival from injury is time-dependent, with this dependency expressed within Cowley’s (1976) concept of the Golden Hour. Media criticism in 2007 of a perceived delay in treatment for seriously injured soldiers in Afghanistan prompted analysis of a previously unquantifiable timeline. In a sample of 528 patients transported by helicopter over 13 months, it identified a median time from injury to surgery of 99 minutes for the most seriously injured category (T1 on the *Triage Sieve*, see Figure 4.4). While this proved achievement of the mandated maximum 2 hours to surgery within NATO policy—and defused the political tension from media criticism—it still fell short of clinical aspirations.

This milestone in being able to accurately measure the timeline was achieved through cultural change to insist the paramedic verified all timings with the Joint Operations Centre on conclusion of the incident and recorded them on the patient

report form. Superficially this appears simple and obvious, but the inertia to record pre-hospital information in the combat setting was institutionalised, a fact demonstrated by American allies (Therien *et al* 2011) who identified that only 18.6% of 'battle casualties' from Afghanistan had pre-hospital information recorded on the US military trauma registry.

The initiative has been a catalyst to continually measure, report and further improve timelines, which have serially fallen to below 60 minutes in subsequent phases of the campaign.¹² This is deduced to be a combined feature of improved helicopter resource availability; changes in tactics to launch the helicopter; and a reducing geographic area of responsibility (with correspondingly shorter flight times). However, the explicit effect of time on improved and 'unexpected' outcomes has not been proven in this population: it is a supposition rather than a causal link and gap that demands academic scrutiny.

4.8 Chapter summary

This chapter has described the transformative changes to the organisation of the DMS and to operational processes to improve the clinical governance of combat trauma. Without this governance framework that provides the evidence of system weaknesses on a day-to-day basis, it would not have been possible to promote either the culture or momentum for sustained change.

This chapter has also demonstrated the consequences of failure to adopt a solution to prevent in-hospital cardiac arrest within the NHS, which at its best can be explained by the inertia of a large organisation to change and at its worst is institutional negligence to prevent avoidable deaths.

The next chapter turns to the revolution in technology and how advances in equipment to support combat casualty care have been exploited.

¹² Verified through internal organisational reporting from data held on the Joint Theatre Trauma Registry.

5. Technological Revolution

5.1 Tourniquet is not a dirty word

Paper 14	Brodie S, Hodgetts, T, Ollerton J, McLeod J, Lambert P et al.
TECHNOLOGY	Tourniquet use in combat trauma: UK military experience.
(TOURNIQUET)	<i>JR Army Med Corps</i> 2007; 153(4): 310-313.

The conceptual re-introduction of tourniquets, and the internal organisational resistance this generated, has been highlighted in Section 3.3. The UK's clinical evidence for the utility of tourniquets comes from peer review of critically hypovolaemic multiple amputees following blast injury (Box 5.1).

4½ years continuous UK military experience in Iraq and Afghanistan from 2003-7 was analysed for the impact of tourniquets in first aid. 107 tourniquets were applied to 70 patients. Most applications (64/70 patients) occurred after 2006, when tourniquets were issued to individual soldiers. 87% (61/70) survived their injuries. There were reversible complications in 3 patients, none of which contributed to unnecessary limb loss.

Traditional mathematical modelling (Injury Severity Score, TRISS Methodology) characteristically underestimates the severity of injury with multiple amputations, as only one limb can be scored. Peer review identified survival in a cohort of patients with a combination of multiple limb amputation, physiological evidence of critical hypovolaemia and a requirement for massive transfusion at hospital. These 'clinical unexpected survivors' received tourniquets at the point of wounding, and their immediate survival to reach hospital was attributed to this.

Box 5.1: *Combat Tourniquet: UK Military Experience*



Figure 5.1: *The Combat Application Tourniquet—individual issue since 2006*

Perhaps more powerfully is the overwhelming cultural acceptance of tourniquets as a life-saving intervention by the individual soldier. Soldiers have observed how early treatment saves the lives of their friends and tourniquets have become deeply embedded in contemporary regimental legend. In some respects their value has become distorted with a known practice to ‘pre-apply’ tourniquets to the thighs prior to combat or to incorporate tourniquets within combat clothing (Figure 5.2).



Figure 5.2: *Integrated Tourniquet Clothing System*

As Sloan observes, technology advances may underwrite a military revolution, but they must be absorbed into revised doctrine and supported within adapted organisational structures before a revolution is possible (Sloan 2002). Boot echoes the sentiment when he states that ‘technology creates the potential for a military revolution’ (Boot 2006, p.10). What both analysts are saying is that technology precedes revolution. But is this the case for medical technology advances? Has there been purposeful primary technological innovation, or purely serendipity? Sloan

further claims that the technologies that underpin a military revolution are often developed in the civilian sector and are then adapted or exploited for military use. This assumption is challenged within military medicine, where a military requirement can be demonstrated to drive a primary military solution.

5.2 Volcanic dust and crushed shellfish applications

Paper 8	Hodgetts T, Russell R, Russell MQ, Mahoney P, Kenward G.
TECHNOLOGY	Evaluation of clinician attitudes to the implementation of novel
(HAEMOSTATICS)	haemostatics. <i>JR Army Med Corps</i> 2005a; 151:139-41.

In October 1993, US Rangers and Delta Force were engaged with Somalian militia in the Battle of Mogadishu where 17 American soldiers were killed. The details of the ultimately hopeless struggle to control bleeding from a groin wound of one soldier are captured in the book *Black Hawk Down* (Bowden 1999) and this frustration was transferred into a challenge to industry, with the model of major groin vessel injury recreated in the laboratory in terminally anaesthetised pigs (Alam *et al* 2003). The resulting innovations have re-set the bar of expectation for what can be achieved to control external bleeding from ‘junctional’ wounds—that is, wounds in the groin, axilla (armpit) and neck with injury to major blood vessels, where a tourniquet is ineffective or, in the case of the neck, contra-indicated.



Figure 5.3: QuikClot® powder applied to British combat casualty during surgery

The first of these innovations was QuikClot®, a zeolite powder derived from volcanic rock (Figure 5.3). When swine modelling confirmed its efficacy (Alam *et al* 2004) it was rapidly approved for military medical use in both the US (from 2003) and UK (from 2004), and later consolidated within BATLS training (Hodgetts 2006b-c) and clinical doctrine (Hodgetts 2007e). QuikClot® was introduced at the same time as a new elastic bandage and the Combat Application Tourniquet. Collectively these

interventions were referred to as 'novel haemostatics' and I developed a bespoke package to augment existing training materials, facilitating the rapid adoption of these innovations. **Paper 8 (Hodgetts et al 2005a)** describes the impact of this training on confidence to treat complex combat wounds—a 'before and after' training questionnaire that identifies a highly significant improvement in confidence to treat traumatic amputation ($P<0.0001$) and ragged groin wound ($P<0.0001$). Of the 86 clinical staff who completed both questionnaires, 94% believed there was benefit from the new techniques; 91% believed the elastic field dressing was an improvement over the traditional first field dressing; 98% believed the combat application tourniquet was an improvement over the Samway tourniquet;¹³ 100% believed that the availability of *QuikClot*® improved the effectiveness to control external bleeding; and 97% believed the potential benefits of *QuikClot*® outweighed the potential risks.

The first human case series of *QuikClot*® use was of 103 casualties, which included 69 combat casualties in Iraq, the remainder being in the US civilian setting. The overall effectiveness was reported as 92% (Rhee et al 2008). Importantly, although outside the scope of initial development intention, 20 of the cases were of internal use by surgeons to stop solid organ bleeding (lung, liver). In this respect, clinicians were pushing the boundary of a step change innovation from the outset (Figure 5.3).

However, *QuikClot*® powder had important side effects. In particular it generated enough heat to cause a skin burn if the skin was not dried before application. Together with the difficulty of applying a powder deep into a wound, confounded by a hostile environment (wind; or turbulence inside a medical evacuation helicopter), the UK recommendations were for use no further forward than a professional Combat Medical Technician and as a two-person technique (**Hodgetts 2007e**). This left the door open for aggressive market competition and encouraged serial incremental innovation to minimise side effects and maximise ease of use by a single field operator (Sondeen et al 2003).

In 2006, MoD was able to introduce a safer agent that generated no heat (chitosan—derived from crushed shellfish), and was impregnated into a stiff 8x8cm bandage. Additionally, an individual soldier could effectively apply it. This was the *HemCon*®

¹³ This is a rubber tube that has been in use since WW2.

bandage and it was pushed as far forward as the Army Team Medic. *QuikClot®* was retained for use as an alternative by professional medical staff.



Figure 5.4: *HemCon®* being applied to a ballistic limb wound

[Colonel Hodgetts is the clinician applying HemCon®]

A challenge when introducing these new agents was to develop a realistic training model. Soldiers unused to dealing with bleeding would not be prepared effectively if their only training experience was a 'dry' model where there was no activation of the haemostatic agent. My academic department (ADMEM) designed an innovative training model utilising packed red cells and plasma that had exceeded its shelf life and was destined for incineration (Moorhouse *et al* 2007, Figure 5.5). This was infused through a simulated large vessel (urinary catheter) at the base of a large wound (section of belly pork with skin, fat and muscle). I effectively applied this model for the first time in Iraq and Afghanistan to give confidence in the use of topical haemostatics to both Team Medics (advanced first aid providers at the point of wounding) and hospital Emergency Department staff (Figure 5.6).

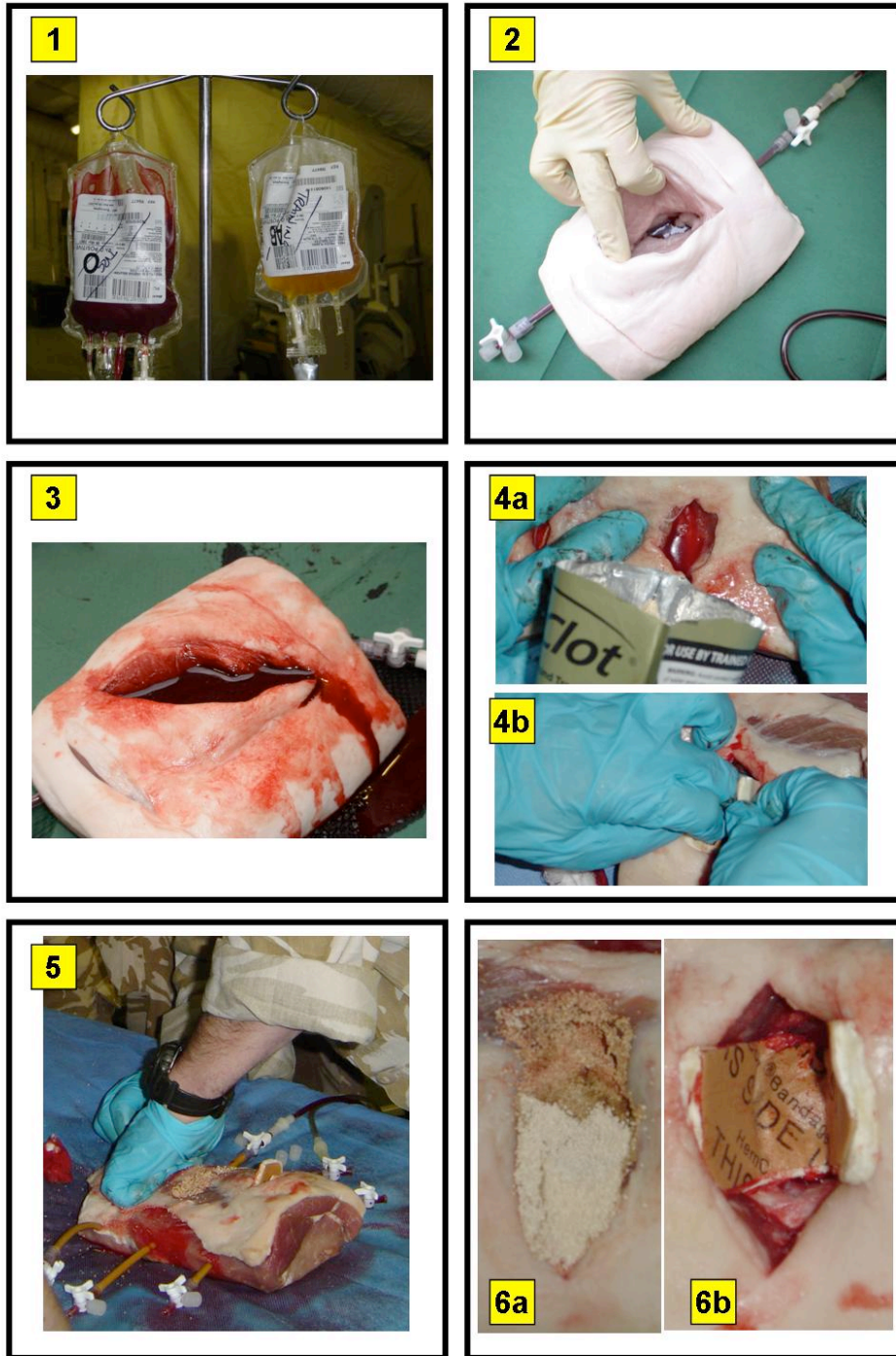


Figure 5.5: *A realistic model for topical haemostatic training*

- (1) Expired red cells and plasma are used to activate the products; (2) A piece of belly pork is prepared with a urinary catheter in the base of a 'wound'; (3) Blood products infused through the catheter are released into the wound through an incision in the catheter wall; (4a) *QuikClot*® is applied and (4b) *HemCon*® is applied; (5) Pressure is applied into the wound through a dressing; (6a) Activated *QuikClot*® in situ and (6b) Activated *HemCon*® in situ.



Figure 5.6: *Team Medics training in the field hospital with HemCon®*

[Colonel Hodgetts is shown far left]

A further step change has generated pliable ribbon gauze impregnated with a chitosan-based agent that performs superiorly in the laboratory (Kozen *et al* 2008) and has the important added advantage of being easily packed into large, irregular wounds—this *Celox Gauze®* has replaced both products in UK from 2010 for use by all providers from the Army Team Medic to the field hospital surgeon.

The rapid serial adoption of the topical haemostatic agents highlights the adaptability of the organisation to maintain an emergent strategy and to respond to repeated innovation that was being stimulated by operational experience. It is an illustration of constantly revising the processes of ‘battle’ and repeatedly amending the rules of the game. But this mature approach to serial innovation is not invariable within the military. In 2005 there was a public and acrimonious disagreement between branches of the US Department of Defence regarding the optimal haemostatic dressing to be universally accepted, which stemmed from a conflict of interest. The US Army had conducted the research to support *HemCon®*, while the US Marines had conducted the research to support *QuikClot®*. The result was the open undermining of confidence in relative product performance, ultimately requiring Congressional adjudication (Little 2005). As Defence budgets contract in an age of austerity and the Defence industry becomes smaller and more competitive, the model for future innovation requires careful consideration: an increasing partnership seems logical and inevitable, but this conflicts with UK Defence’s traditional concerns of probity and propriety that are a barrier to commercial collaboration.

5.3 Paediatric Triage

Paper 1 TECHNOLOGY (TRIAGE)	Hodgetts T, Hall J, Maconochie I, Smart C. The Paediatric Triage Tape. <i>Pre-hospital Immediate Care</i> 1998; 2: 155-159.
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Effective prioritisation of children in the pre-hospital setting is of even greater importance than for adults: but what is the rationale for this? Paediatric resources are typically limited in a district general hospital and are extremely limited in a field hospital, where the military mission does not generally cater for specialist paediatric staff within its core capability. Paradoxically, the volume of paediatric trauma is disproportionate in a field hospital—although children consistently make up only 2-3% of field hospital attendees (Walker, Russell, **Hodgetts** 2010; Gurney 2004) these are skewed because of eligibility criteria to critically injured cases, with 100% hospital admissions being trauma¹⁴ and 88% cases being triage categories T1 or T2 (Walker, Russell, **Hodgetts** 2010).

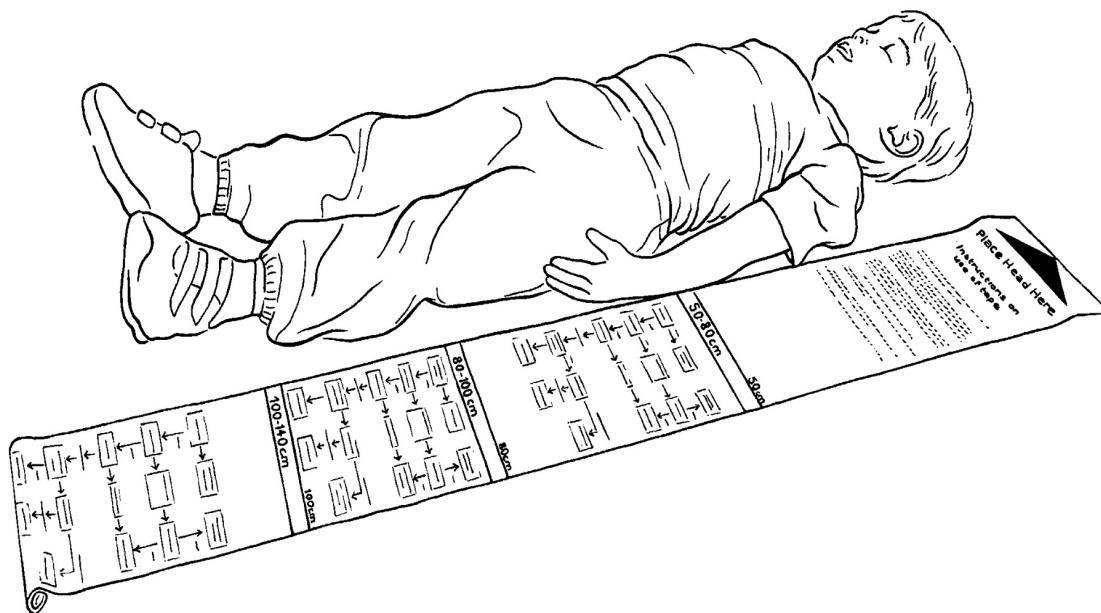


Figure 5.7: Paediatric Triage Tape

Physiological triage systems are more consistent than anatomical systems (**Hodgetts** and Mackway-Jones 1995a) and physiological systems have been widely distributed into military practice from first aid to hospital care (**Hodgetts** 1999b, 2006b, 2008a-b). Nevertheless, there is a risk of over-triage if adult systems are

¹⁴ British Field Hospital, Helmand Province, Afghanistan, May 2006 to December 2007.

applied to children and this will potentially misdirect the limited hospital resources. The Paediatric Triage Tape (PTT, Figure 5.7) uses the relationship of age, length and weight to adjust the adult Triage Sieve (Figure 4.4) for representative children's values. Best practice is incorporated into the physiological assessment, recommending that capillary refill is performed on the forehead, which together with the sternum are the only sites that generate a true Gaussian distribution (Strozik *et al* 1997)—the sternum is not recommended primarily as time would be added to expose the child's chest during what should be a very rapid assessment. Further, the chosen 'normal' ranges of vital signs exploit the limited best evidence available (Poets *et al* 1993) supported by expert consensus (ALSG 1996).

In a validation of PTT in a children's hospital in South Africa (Wallis and Carley 2006), PTT had a very high specificity to rule out non-T1 patients (98.6%), but a low sensitivity to detect in the field those ultimately determined to be seriously injured (37.8%). The over-triage and under-triage rates were within the range deemed unavoidable by the American College of Surgeons.

Paper 7 ORGANISATION (SYSTEMS)	Hodgetts T, Mahoney P, Mozumder A, McLennan J. Care of Civilians during Military Operations. <i>International Journal of Disaster Medicine</i> 2005b; 3: 3-24.
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Linked to the requirement to effectively triage children because of the need to prioritise limited treatment resources, a formal analysis of the military's capability to treat civilians on operations has been undertaken (**Hodgetts *et al* 2005b, Paper 7**). The catalyst for the review was the anxiety in treating a substantial number of injured children during the Iraq War of 2003 (**Hodgetts 2004c**), without the necessary specialist equipment. International Humanitarian Law, expressed through the UN Rights of the Child to which the UK is a signatory, directs that if there is a responsibility to treat children then the staff training and supporting equipment must be appropriate. The military's engagement in treating civilians on operations has been an enduring area of friction with civilian agencies (International and Non-Government Organisations) where boundaries of responsibility have been contested, the trigger for use of the military as a 'last resort' has been inconsistent, and the independence and impartiality of humanitarian organisations is perceived to be undermined by association with the military. In order to build consensus through mutual understanding a Delphi study (**Paper 7**) drew together an expert panel of 40 civilian and military actors and achieved consensus of >80% on 218/309 (70.5%)

statements over 3 rounds. This is a landmark for setting the standards for future civil-military cooperation. There are, however, 2 criticisms that can be fielded: the first is the balance of the panel composition (35/40 were military) and the second is the background of the civilian actors. The willingness to interface with the military is on a spectrum ranging from close collaboration through to uncomfortable coexistence: only civilian agencies that were collaborative by nature participated in the study.

5.4 Wider technology advances

There are considerable wider technology advances that confirm a revolution. So far only those advances relating to first aid have been described that I directly influenced. To understand the full impact of technology on military medicine in the last decade would require a detailed analysis of the innovations in pre-hospital emergency care (bone infusion devices; surgical airway kit; chest drain kit), field hospital resuscitation (platelet aphaeresis¹⁵; thromboelastography¹⁶; recombinant factor VIIa), imaging (CT scan; ultrasound; digital X-ray; telemedicine); aeromedical evacuation (elastomeric pumps for in-transit pain relief); and rehabilitation (limb prosthetics). Some of these are commercial off-the-shelf (COTS) or militarily adapted COTS ('MOTS') innovations as Sloan (2002) suggests, and some are bespoke to the military requirement. Imaging and coagulation advances are selected for further analysis because of their profound importance for emergency medicine and, in the latter, my direct influence.

5.4.1 Imaging advances

In the first Gulf War in 1991, imaging to support clinical decision making was confined to conventional radiography, generating x-ray images on celluloid using a wet processing technique that was dependent on the continued supply of reagent chemicals. Capability was enhanced in Kosovo in 1999 by the availability of portable ultrasound for use in the Emergency Department to detect free blood in the abdomen and prompt explorative surgery: however, only the radiographers (radiology technicians) were trained to do this and their experience was variable (**Hodgetts et al/ 2000a, Paper 3**). By 2003 and the second Gulf War, doctors in the trauma team were learning a focused ultrasound technique, which has continued to gain momentum as an immediate diagnostic and decision-making tool. Computerised tomography (CT) scanning was first deployed as a Land capability within a UK field hospital in 2004. Prior to this, patients had to be moved to another country for

¹⁵ Harvesting fresh platelets from donors in the operational Theatre.

¹⁶ An analyser that displays how a patient's blood is clotting graphically and in real-time.

diagnosis and treatment (e.g. Kosovo to Macedonia; **Hodgetts et al 2000a, Paper 3**)—a Hobson’s therapeutic choice as ‘sick patients travel badly’ (**Hodgetts and Turner 2006f**), but effective treatment requires accurate diagnosis. CT in the field hospital allowed determination of whether such a move was beneficial, and what treatment to optimise outcome should be done prior to movement. Subsequently, the reliance on whole body CT as a screening tool in severe blast injury has modified the resuscitation process, has led to two scanners being deployed simultaneously with a substantial enhancement in the sophistication of the machines (MoD 2010), and has demanded the routine deployment of radiologists (specialist doctors). When coupled with the recent parallel implementation of digital x-ray (BBC 2010) to replace wet film (which has the triple benefit of removing hazardous chemicals from the process, eliminating a logistic burden, and shortening decision-making in resuscitation by ~10 minutes through instant image display), it is reasonable to assert that imaging is a prime example of combined technology, organisation and clinical practice transformation.

5.4.2 Coagulation advances

Paper 16 TECHNOLOGY (DRUGS)	Hodgetts T, Kirkman E, Mahoney P, Russell R, Thomas R <i>et al.</i> UK Defence Medical Services guidance for the use of recombinant Factor VIIa in the deployed military setting. <i>JR Army Med Corps 2007g; 153(4): 307-9.</i>
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For 25% of seriously injured patients who survive to reach hospital there is a continuing threat that relates to an inability of the blood to clot effectively: this is known as the *coagulopathy of trauma* (Brohi *et al* 2003). A 5-fold increase in mortality with early coagulopathy has been quantified in civilian practice (MacLeod *et al* 2003), but the advances in treatment to reverse the disorder have arisen in contemporary combat casualty care (Holcomb *et al* 2007). Additionally, the statistically proven higher severity of combat trauma over civilian trauma (**Hodgetts et al 2007a**) can be assumed to have the same if not higher relative mortality when all other factors are equal, but as this thesis has demonstrated all other factors are not equal.

Trauma resuscitation in civilian and military practice until 2007 concentrated on replacing lost blood with red cells and crystalloid. This is not intuitive: it restores oxygen carrying capacity, but fails to restore any capacity to support coagulation. A

clinical doctrine and organisational change to resuscitate aggressively with plasma alongside red cells in a 1:1 ratio supplemented by boosts of platelets (Jansen *et al* 2009) has a teleological foundation. It has created a marked logistical challenge for the National Blood Service and the Royal Air Force to manage a 5,000-mile blood product supply chain, and has stimulated a new application of technology to monitor the effectiveness of treatment—the thromboelastogram (TEG)—which had been applied successfully in elective liver surgery, but was not being exploited to manage the coagulopathy of trauma.

Parallel advances woven into and strengthening this new fabric of field hospital resuscitation have been new doctrine, training and equipment to support platelet aphaeresis, as the expeditionary supply chain is too fragile to fully support the requirement (platelets are a scarce resource in the UK, with a shelf life of only 3 days); and the contentious off-label use of the haemophilia drug recombinant Factor VIIa, or 'rFVIIa' (Hodgetts *et al* 2007g, **Paper 16**), which is exceptionally expensive but has proven life-saving in exceptional circumstances (Kenet *et al* 1999; Williams *et al* 2003).

The need for a clear and rational UK policy for rFVIIa was driven by media criticism in the UK (BBC 2006) and US (*Los Angeles Times* 2006) that its off-label use constituted experimentation and was an indicator of 'dereliction of duty' and 'moral bankruptcy' (*Guardian* 2006). The ill-informed criticism by a poorly briefed Member of Parliament ignored the fact that 80% of UK Intensive Care Units were prepared to use the drug in the same clinical circumstances (telephone survey of 40 units); that European guidelines from 2006 supported the use of rFVIIa to control traumatic haemorrhage when other measures had failed; that large animal evidence demonstrated safety and (in some studies) improved outcome; and that human evidence demonstrated a decrease in transfusion requirements, particularly relevant when there is a fragile and extended supply chain.

These changes have re-written the rule book of fluid resuscitation following injury, represent a pronounced difference in trauma care delivered by DMS compared to NHS, and through improving survival have changed the expectation of soldiers, their families, their commanders and political leaders forever. Whether this is realistically sustainable will be discussed later.

5.5 Chapter summary

This chapter provides detail of the technological revolution in combat casualty care with examples focused on equipment and drugs to prevent avoidable death from external and internal haemorrhage. However, technology changes have been broad based and insight is given to the advances in imaging and paediatric triage, both of which assist critical decision-making and prioritisation of clinical action.

In the next section the key themes from the three sections of evidence (doctrinal, organisational and technological revolution) are drawn together to summarise the argument to support a *Revolution in Military Medical Affairs* (RM2A) and to prove the *Homunculus Casualty Theorem*.

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PART C



THE ARGUMENT

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6. Discussion

6.1 Clarifying the questions

The fundamental question underpinning the thesis asks whether or not a *Revolution in Military Medical Affairs* (RM2A) has occurred. Subsidiary to this, and the assumption of proof of RM2A, is quantification of how the body of work in this submission has contributed to the revolution (refer to Chapter 1, page 16 for full articulation of the research questions). Finally there is a determination of whether the direction of developmental effort has matched the genuine clinical need—this is the *Homunculus Casualty Theorem* and the null hypothesis asserts they are not matched.

6.2 Proof of RM2A

The weight of evidence presented, which brevity constrains from being entirely comprehensive, is sufficient to assert that the Defence Medical Services have undergone a *Revolution in Military Medical Affairs* (RM2A). Far from being confined to technological advances (which is characteristic of the traditionally described RMA), substantial reform has occurred in parallel in organisational structure, systems of training, and operational processes.

Collectively, there is substantial proof to satisfy Lambeth's (1997) criteria (a change in military doctrine, operational concepts and organisational concepts, with technological innovation), Krepinevich's (1994) criteria (technological change, systems development, operational innovation, organisational adaptation) and Cohen's (2009) criteria (evidence of a change in organisational structure, processes and outcomes) for an RMA; additionally, Toffler's (1993) conditions are satisfied for a 'true revolution' rather than a lesser 'sub-revolution' (a change in equipment, team organisation, training, doctrine and tactics).

The succession of radical changes has strategic consequences as a tangible manifestation of upholding the covenant between the government and its Armed Services—that is, the investment (political will and resources) in supporting combat casualty care developments fulfils the government's obligation in demonstrating a duty of care to its soldiers. Furthermore, in medical terms at least, the evidence refutes Freedman's claim that only the United States has the economic resources and infrastructure to follow the revolutionary path (Freedman 1998).

6.2.1 Doctrine

Fundamentally, a doctrinal shibboleth has been challenged and overturned—ABC to <C>ABC (**Hodgetts et al 2006, Paper 9**)—with proven improved outcome resulting from the related systemic transformation (Russell, **Hodgetts et al 2011, Paper 20**).

A new doctrinal framework of Damage Control Resuscitation has been created to encapsulate the common aim to reduce blood loss, optimise oxygenation and maximise outcome from point of wounding to intensive care (**Hodgetts et al 2007c, Paper 15**), which is supported by comprehensive, multidisciplinary Clinical Guidelines for Operations that uniquely combine trauma, medical, toxicological and environmental emergencies in a single system (**Hodgetts 2008a**).

6.2.2 Organisation

Emergency Medicine has been transformed from a Cinderella specialty to a core specialty within the ten years from its first operational deployment in 1999 (**Hodgetts et al 2000, Paper 3**), with my leadership evident in the changes in education and trauma system governance (Smith, **Hodgetts et al 2007, Paper 11**; **Hodgetts et al 2007d, Paper 12**; Willdridge, **Hodgetts et al 2010, Paper 19**).

A fundamental change to the underpinning treatment principles has demanded a fundamental change in training from individual first aid through to hospital-based resuscitation: this is reflected in the transformation of the Battlefield First Aid programme (**Hodgetts et al 1999b, Paper 2**) and the Battlefield Advanced Trauma Life Support Course (**Hodgetts et al 2006c-e, Paper 10**). In parallel, a novel international approach to major incidents has been implemented and evaluated (**Hodgetts 2000, Paper 4**).

Evidence for changes in team organisation, training and tactics is also provided by the development of an evidence-based approach to preventing avoidable in-hospital cardiac arrest (**Hodgetts et al 2002b-c, Papers 5 & 6**). This experience has given an important insight into the differences in NHS and DMS culture when implementing change and the barriers within NHS to adopting military innovation on a national scale.

6.2.3 Technology

The introduction of novel haemostatic dressings has required parallel training to be developed and the effectiveness of this training to be evaluated (**Hodgetts et al 2005, Paper 8**). Unlike the haemostatic dressings, the reaffirmation of tourniquets as an essential component of first aid does not represent the invention of a new clinical capability. Yet it does represent the re-acceptance of practice that had become relegated to taboo. This has been a 'revolution' in two meanings of the word—a *rapid and profound change* in attitude and a *cyclical return* to earlier accepted practice. In revolution, resistance can be expected. Internal resistance was from orthopaedic consultants who feared injudicious use would lead to salvageable limbs being avoidably lost (Parker and Clasper 2007). This has proven to be unfounded (Kragh et al 2009) and the provision of tourniquets to every UK and US soldier has been demonstrated to be lifesaving (Brodie, **Hodgetts et al, Paper 14**; Kragh et al 2008).

6.3 Contribution to Revolution

The evidence identifies I have acted as a transformational leader to drive the concepts, guidelines, training, organisation and governance of the UK's combat casualty care system, focusing in delivery on the 'acute care' components (pre-hospital and emergency medicine). Emergency Medicine has been the vanguard for academic advancement of combat casualty care and a catalyst for development of the strategic cluster of clinical-academic departments within the Royal Centre for Defence Medicine, each adding substantially to the body of medical knowledge.

6.4 The Homunculus Casualty Theorem

Just as the functional proportions of man's brain are represented in the homunculus (Figure 6.1), the proportion of lethal or debilitating combat injuries are represented in the homunculus casualty. The question is whether the effort within the RM2A matches the relative importance of each injury—and how, perhaps, the homunculus casualty could evolve over time.

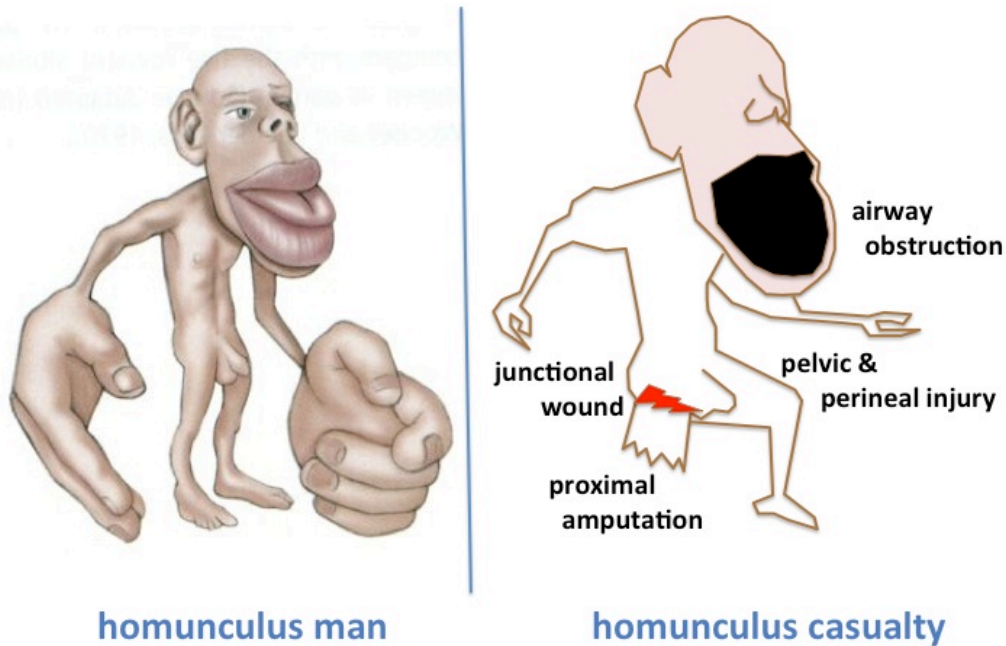


Figure 6.1: *Homunculus Man and Homunculus Casualty*

The emphasis for the early management of severe combat trauma is on stopping catastrophic external bleeding. The rationale is that acute haemorrhage accounts for up to 50% of conventional deaths on the battlefield (Bellamy 1984) and up to one third of historical deaths are estimated to be preventable by early intervention (Bellamy 1986), particularly by arresting bleeding from limbs. The homunculus casualty is dominated by a proximal (above knee) amputation and a junctional groin wound (Figure 6.1), reflecting these treatable injury patterns. Linked to this are the introduction of self-applied tourniquets and topical haemostatics, together with advances to replace circulatory volume (adult intraosseous infusion) and treat the associated coagulopathy (damage control resuscitation; haemostatic resuscitation).

Recent evidence confirms the importance of external haemorrhage control, with 31% of potentially avoidable US military deaths in Iraq and Afghanistan attributed to compressible wounds (Kelly et al 2008). What is less well represented on this model is that 69% of potentially avoidable haemorrhage deaths in this series are from non-compressible haemorrhage in the thorax and abdomen.

Hypoxia from airway obstruction is a widely accepted cause of early avoidable death. Primary blast to the thorax has been recognised to cause reversible apnoea since 1942, related to vagal stimulation (Sawdon *et al* 2002). The homunculus casualty

therefore has a large airway. Skills given to individual soldiers to open and clear the airway and provide supportive ventilation until the patient starts to breathe are founded in credible science.

The US military also places a high emphasis on tension pneumothorax, providing equipment for needle thoracoscentesis far forward at the level of 'Combat Lifesaver'—a non-medical soldier trained in advanced first aid (the UK equivalent being the 'Army Team Medic'). This decision is based on Vietnam War data that identifies tension pneumothorax as a cause of death in up to 4% cases (McPherson *et al* 2006). Diagnosis is known to be subjective, with civilian pre-hospital series demonstrating wide variability from 0.7% to 30%, and in patients breathing spontaneously it is typically a gradual onset (Leigh-Smith and Harris 2005). Contemporary UK military data has not demonstrated any significant prevalence of tension pneumothorax in immediate trauma deaths (**Hodgetts *et al* 2007, Paper 12**) and consequently no need for intervention by non-medical soldiers. Rather, the UK approach recognises the potential for failure of needle thoracoscentesis and the potential for unintentional harm with non-professional intervention.

It is a reasonable deduction that the homunculus casualty is different in these two military populations and the prevalence of tension pneumothorax has altered between conflicts as a result of improved thoracic protection (body armour), and/or a change in injury mechanism (the balance between blast:gunshot:blunt injuries) and/or a change in the perceived presence of the condition (criteria used for diagnosis). Every future campaign may be expected to develop its own homunculus as the weapons, external environment and enemy *modus operandi* change. The medical challenge is having systems in place that facilitate adaptation by recognising the evolving injury patterns and providing iterative feedback on the impact of changing both protective measures and treatments.

A limitation of the homunculus casualty is that it is an anatomical model and does not represent pain, which is a ubiquitous component of serious injury. Battlefield analgesia has been serially identified as a weakness in contemporary capability (**Hodgetts *et al* 2006; Hodgetts and Findlay 2012**) despite commercial off-the-shelf solutions and published internal innovation—rather it remains substantially entrenched in the same approach applied during the First World War. Figure 6.2 adapts the model in an attempt to include this key component of injury.

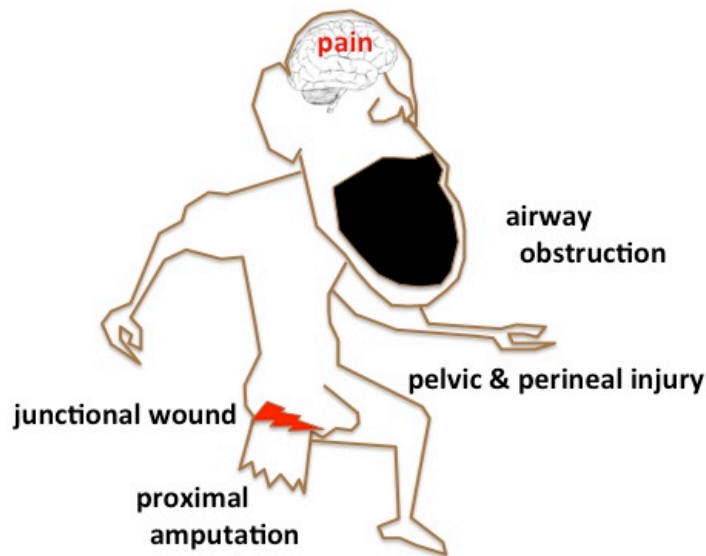


Figure 6.2: *Homunculus Casualty*—adapted to include pain

6.5 Chapter summary

This chapter has drawn together the evidence to answer the research questions and prove a *Revolution in Military Medical Affairs* (RM2A), and to prove I have made a substantial contribution to the medical knowledge and understanding that underpins the concepts and practices driving the revolution. There is also proof, through the *Homunculus Casualty Theorem*, that developmental effort has been focused appropriately and proportionately to find novel treatment approaches to improve outcome from the most likely consequences of combat injury.

It is now relevant to look to the future to determine the requirement for continued revolution and to establish how the advances in war can enhance our civilian healthcare systems in peace.

PART D



THE WAY FORWARD

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7 Future direction

In determining the future direction to further develop combat casualty care capability and the transfer of learning to civilian trauma systems the following questions require answers:

- How does civilian trauma system performance benchmark against the military system?
- How can advances in combat casualty care be transferred into civilian healthcare system benefits?
- What have been the conditions for revolution and will these conditions endure?
- What have been the unintended consequences of revolution and how will these shape future direction?
- What is the future character of military medicine and how will this influence capability development?
- What are the future research opportunities stemming from this study?

7.1 Benchmarking performance

Paper 17 OPERATIONS (PERFORMANCE)	Hodgetts T, Davies S, Russell R, McLeod J. Benchmarking the UK military deployed trauma system. <i>J Roy Army Med Corps</i> 2007a; 153(4): 237-8.
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The concept of a strategic drift developing between UK military and civilian major trauma capabilities was introduced in Section 1.6 and expressed in Figure 1.2. Further, the cohort of survivors of combat injury that are judged likely to have died if managed within a civilian system were described in Section 4.6.1, with sub-analysis of the improved military system performance for traumatic cardiac arrest presented in Section 4.6.2.

Paper 17 (Hodgetts *et al* 2007a, p.238) provides greater understanding of the detail of how the systems benchmark and states that:

‘While there is no doubting there are pockets of exemplary trauma practice in the NHS, the inconsistent and generally poor standard of national care that

NCEPOD¹⁷ describes reflects an NHS culture that fails to assign the same importance to the systemic management of major trauma as the DMS.’

The evidence for this assertion comes from a contrast of the seniority of the trauma team leader out of hours (a resident, 24-hour consultant-led team in all cases in the military compared with 3.3% of 183 civilian hospitals); inadequate pre-hospital, physician-delivered airway management (80.6% of military major trauma retrieved by a physician-led helicopter team compared with 11.7% civilian cases), and poor supervision of on-going case management (only 40% of NHS cases were reviewed by a consultant within 12 hours, compared to all field hospital cases managed by an integrated military consultant team from the outset).

7.2 Civilian adoption of military innovation

The clinical and political imperative to continuously develop combat casualty care standards has been a sustained casualty load on campaign operations. This imperative will likely be greatly diminished in a shrinking military organisation that returns to preparing for contingency operations in an age of austerity. The survival of the learned clinical practices is therefore dependent on them being absorbed into the NHS. The assumption is that all the novel practices are relevant to the civilian context.

There is historical precedent in transferring military medical innovation in conflict to civilian healthcare benefits in peace: Box 7.1 describes medical ‘revolutionary’ advances over the last 350 years and draws comparison with contemporary innovations. The key success factor is to understand why adoption of innovation may predictably fail and to overcome the barriers.

In 2011 the Chief Executive of NHS stated the importance of placing innovation at the heart of NHS culture and processes. In the associated strategic document, *Innovation, Health and Wealth* (NHS 2011), the predictable barriers to innovation adoption were described (Figure 7.1).

¹⁷ National Confidential Enquiry into Patient Outcomes and Deaths, 2007

- ✦ The treatment of war wounds with egg yolk and turpentine, rather than boiling oil, by Ambroise Paré in the mid-16th century (Paget 1897): a benchmark for the haemostatic wound dressings *QuikClot*® and *HemCon*® introduced in 2005-6.
- ✦ The introduction by Baron Larrey, Napoleon's Surgeon Marshall, of 'flying ambulances' (*ambulances volantes*) a dedicated horse and cart manned with litter-bearers for the rapid evacuation of casualties from the battlefield (Crumplin 2007): a benchmark for the specialist medical helicopter-borne team (a 'flying ambulance') enhanced in 2006.
- ✦ The invention of anaesthesia in 1846 to relieve suffering during operative procedures and give the surgeon appropriate conditions for a careful procedure: a benchmark for the benefits of forward anaesthesia during primary helicopter retrieval, coupled with process changes to allow immediate, anaesthetic-assisted resuscitation on the operating table for the most critical casualties.
- ✦ The use of the Thomas traction splint in WW1, a simple technology advance that reduced mortality related to open fracture of the femur from 80% to 16% (Robinson 2009): a benchmark for the impact of introducing one-handed, self-application tourniquets to individual soldiers from 2006 as a simple, life-saving technology.
- ✦ The recognition by the Medical Research Committee (later Medical Research Council) formed in 1913 of the importance of capturing and analysing data on injuries, illnesses and treatment during war (Loudon 2001): a benchmark for the development of a sophisticated trauma governance system, reliant on progressively detailed data collection from 1999.
- ✦ The pressure of clinical needs driving therapeutic and pharmacological advances in WW2, in particular the development of blood transfusion techniques and commercial production of penicillin: a benchmark for the advances in massive transfusion therapy from 2007, including technology for pre-hospital administration of blood, harvesting fresh platelets from donors on operations, improved monitoring of patient response (thromboelastography), and novel drugs (recombinant Factor VIIa).

Box 7.1: Historical Medical Advances and Contemporary Parallels

In direct comparison, the principal reasons for successful military adoption of innovation can be highlighted—access to high quality evidence, data and metrics through the Joint Theatre Trauma Registry; and the capability and tools of senior officers to drive change. The leadership culture to support creativity and evidence-based innovation has shifted: in the Cold War there was a predominantly bureaucratic leadership culture, which has necessarily evolved to an adaptive approach within a sustained campaign. The reality is that a reduction in operational activity will favour a return to bureaucracy.



Figure 7.1: Barriers to Innovation Adoption within the NHS
 [Reproduced from INNOVATION HEALTH AND WEALTH, NHS 2011]

7.3 Conditions for Revolution

There are two domains in which favourable conditions have fostered revolutionary change—these are the political and the socio-cultural. What must be understood is whether these conditions will endure to sustain progressive future developments.

The political rationale to drive RM2A has already been partly established within the context of the Strategic Defence Review 1998 and post-operational analysis of the campaign in Kosovo: the DMS was severely undermanned and perceived to be incapable of adequately supporting major combat operations (HCDC 1999). There is a link to the observation that militaries can endure innovation stagnation if they are non-operational and, as Loo states, how it is ‘no surprise that the most active militaries (US, UK, Israel) are those demonstrating transformation’ (Loo 2009, p.95): campaigns in the Balkans generated casualties, but it is the sustained and high volume of dead and injured from the Iraq and Afghanistan campaigns that have provided the DMS with a continuous political imperative to transform.

Colin Gray claims that the social and cultural circumstances are more important than technological advances in influencing change (Gray 2006). Extending his analysis, it is both the internal organisational cultures and external societal cultures that influence the atmosphere for change. Internal organisational culture was forced to change with the introduction of Emergency Medicine as a specialty in 1994 and its

first operational deployment in 1999: this marked the beginning of a new specialist professional 'ownership' of a system of emergency care from point of wounding to the field hospital. But a clinical cultural change alone was probably insufficient to overcome the traditional bureaucratic conservatism that could be viewed as a brake on innovation—how then has the balance that favours institutional risk aversion been tipped in favour of accepting profound changes? This may be attributed to a societal shift towards casualty aversion.

The literature is rich with analysis of the culture of casualty aversion and the correlation between rising casualty numbers and diminishing public support. Annual UK casualty numbers steadily rose in Afghanistan from 2006-2010: it is therefore logical to deduce that growing public concern has encouraged political support for changes that are expected to improve clinical outcomes. It is also logical, but contestable, to assert that society will be even less tolerant of body bags when the context is not perceived to be a war of necessity—but rather one of choice (Afghanistan), or even an 'unjust' war (second Gulf War). Indirect evidence of the impact of a heightened casualty aversion culture is the absence of any reduction in the DMS capability within the deep cuts associated with the 2010 Strategic Defence Review (UK MoD 2010).

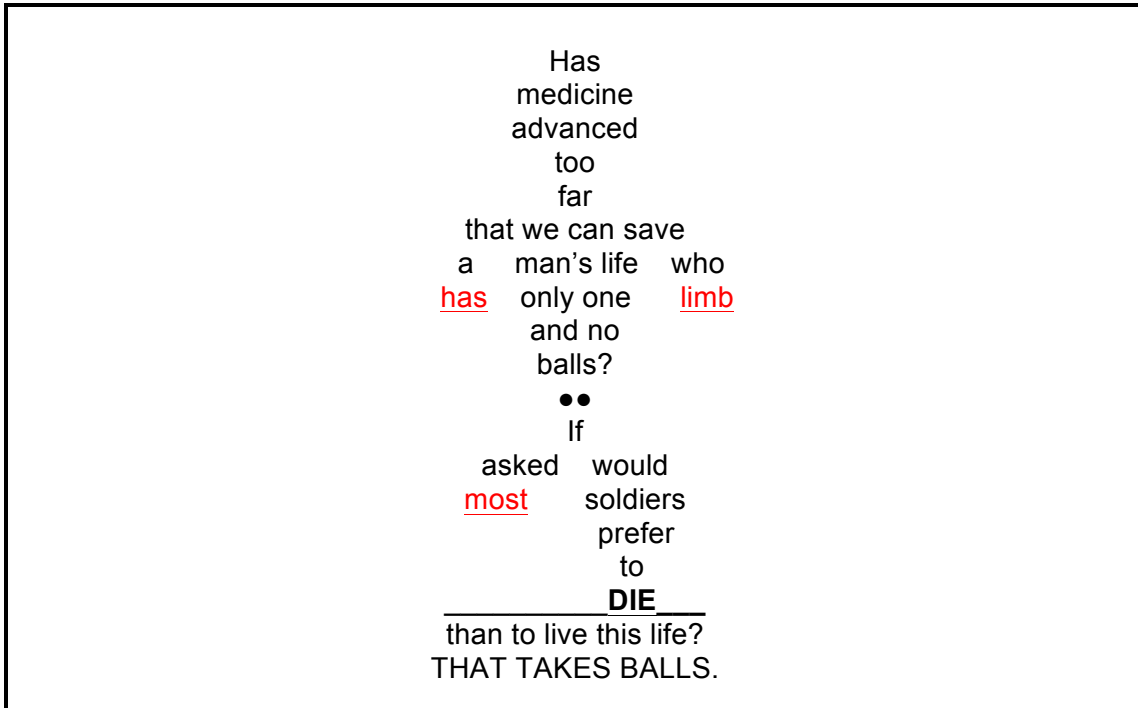
Society's relationship to the injured soldier has therefore probably changed in regard to discretionary wars, and has tangibly changed in regard to the expectation of casualties' survival. Such a change in the relationship of the 'game' to society itself is identified as a mark of a true revolution. However, without casualties being sustained in the future, society's attention will be distracted, the political priority will predictably wane and military medical services will become vulnerable for cost-saving initiatives.

7.4 Consequences of Revolution

The intended consequences of reforming Defence's combat casualty care capability are clear from the outset: improved standards of clinical care with measurable improvement in outcomes. What have become apparent are the unintended clinical and logistic consequences. Principal amongst these is an unexpected growing cohort of severely disabled double or triple amputees, often with associated genital injury. It is beyond the scope of this thesis to debate this dimension in detail, but reflection reveals ethical and social dilemmas.

7.4.1 Ethical challenges

Chief among the ethical challenges is to consider whether medicine to treat combat casualties has advanced too far (Box 7.2). Can it be considered ‘inappropriate’ to continue resuscitation at the field hospital (based on an assessment of severe morbidity), even if it can be ‘successful’ (return of signs of life)? This is an unasked question where political, personal, societal, medico-legal and spiritual answers are likely to differ.



Box 7.2: ‘Balls’, © TJ Hodgetts 2008

Furthermore, should soldiers maintain a Living Will if they do not want to be resuscitated when catastrophically injured? And is society prepared to shoulder the burden of responsibility for additional lifetime physical and psychological support for the severely disabled survivors?

An additional enduring ethical friction when treating civilian casualties of conflict within the military system is whether to be a doctor or a soldier first—this is referred to as ‘mixed agency theory’ (Thomasma, 2003). As a good doctor it is necessary to place the requirements of the patient and the consequences for the patient at the centre of all decisions, a virtuous approach known as *teleology* or *consequentialism*. Where rules are used to assist these optimal clinical decisions it is *utilitarianism*. As a

good soldier it is necessary to give primacy to the requirements of the Commander and maintaining the Commander’s flexibility and freedom of military action—this is *deontology*, where duty, integrity and compliance with legal orders is the driving motivation. This enduring tension is represented in Figure 7.2

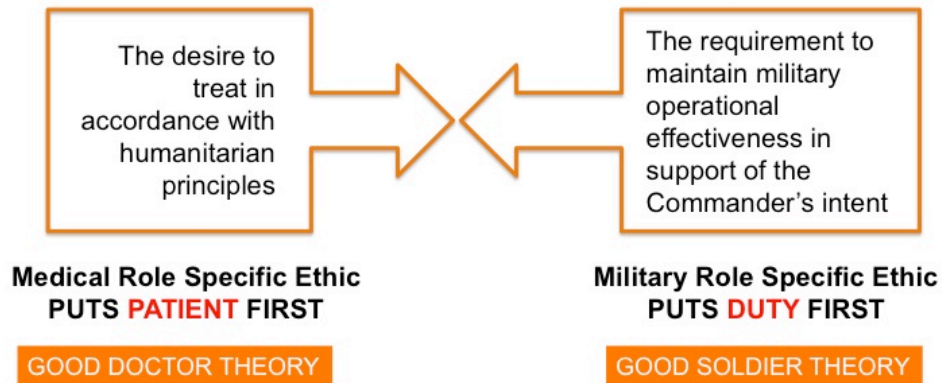


Figure 7.2: *The Tension of Mixed Agency Theory*

The motivation within this thesis to champion serial changes to improve the quality of combat casualty care demonstrates a teleological framework. The invention of ‘rules’ and their widespread distribution¹⁸ (Section 3.5.3) reveals a utilitarian approach. The personal tension I have had to balance with the medical imperative versus the military imperative is illustrated in vignettes from my experience as a Field Hospital Medical Director (Mahoney, **Hodgetts et al** 2011) and in the original war poem in Box 7.3.

7.4.2 Sustainability of heroic medicine

A new culture of heroic operational medicine has evolved, where the maximum effort is expended for every soldier all of the time, applying the full weight of the transformational processes described. The sustainability of this approach is questionable. The DMS has been a high consumer of national blood product stocks: a change in national strategy to sustain stock levels would be predictable if the NHS moves towards the aggressive resuscitation approach that has contributed to improved combat casualty survival. Additionally, high casualty rates in a Major Combat Operation would potentially rapidly outstrip blood resources if heroic resuscitation is widely followed. In this situation it would be essential to manage the expectations of military commanders, politicians and the public.

¹⁸ ‘Trauma Rules’ has been translated into Italian and Japanese; ‘MIMMS’ and the ‘Major Incident Management System’ have been translated into Japanese, Swedish, Italian and Dutch.

1

Admit: don't admit?
There's one bed left: an injured child,
Fell down a well,
Is very sick,
But there's a TIC,
I feel compelled,
For soldiers' sake, to hold that bed.
Admit: don't admit?

2

Treat: don't treat?
He's got no legs, his heart has stopped,
Stood on a mine,
Will likely die,
But shall I try?
Two out of nine
Will get pulse back; we've changed the odds.
Treat: don't treat?

3

Live: or let die?
We've tried for hours, he won't respond,
Fresh donor blood
Was our last card.
Though it is hard
I won't, but could,
Lack courage, not accept the end.
Live: or let die?

Box 7.3: 'Ethical Choices', © TJ Hodgetts 2009

TIC = Troops In Contact

7.5 Continuing the Revolution

Unpacking the consequences of revolutionary change reveals an additional set of challenging questions that relate to future direction. Does the DMS need to stay at the forefront of trauma care, or is being as good as the NHS good enough? Would military commanders generally accept the lesser standard, or would this impinge unacceptably on the moral component of fighting power? Is research investment to further develop capability justifiable when austerity savings are a national imperative? What this boils down to is two simple questions—*should* we continue progress and *can* we continue progress?

There is a moral argument that as war creates the environment for clinical innovation it should be exploited to its full potential as there are ultimately benefits to the whole of society. The counter-argument relates to cost in an age of austerity. Senior national academics have recommended that MoD research should bear the brunt of research cost savings (Sample 2010) to protect civilian research investments. In the case of health this would be a false economy, at least as long as combat operations continue and the political imperative for optimal casualty care endures.

A sensible compromise would be to determine those areas where maintaining primary research is considered essential, through the need to protect a national capability or where no other country has the expertise, and those areas where external innovation can be exploited. An example of retaining national capability is large animal blast injury modelling, where the Dstl [sic] has the world-leading capability. Conversely, an example of exploiting external innovation is haemostatic bandage technology: here research and development (R&D) has been effectively 'outsourced' to industry, while the military retains a horizon scanning process and a process for reliable evaluation before 'creatively swiping' any future new product. The benefit lies in the R&D costs lying externally, together with avoiding the risk of unanticipated side effects following early clinical application.

From the UK perspective the haemostatic agent *WoundStat*® bears witness to this example. The agent was prematurely widely introduced into US military, but then embarrassingly withdrawn due to side effects (NBC News 2008; Kheirabadi *et al* 2010). UK's caution not to over-expeditiously adopt what was superficially an advance in capability was wise in retrospect.

Developing this theme of cost-effective innovation, Max Boot (2006) makes the pragmatic observation that it may not take a lot of money to innovate, particularly in concepts and processes, as the financial investment relates more to product invention. He encourages this *smart innovation* that adds value at little cost.

The thesis draws out examples where smart innovation has occurred. However, it has not yet explained how the integrated changes for acute trauma care, across the Defence Lines of Development, have been used as a stimulus to drive systematic change to improve the neglected area of operational primary health care.

Specifically, I have led an academic review of deployed Role 1 capability (**Hodgetts & Findlay, 2012a and 2012b**) that has identified areas for training, doctrine and

governance improvement at little cost, although recognises the requirement for financial investment in equipment and infrastructure to modernise Role 1 for future contingencies. Central to this is an understanding of how the evolving character of military medicine should be at the heart of shaping future capability.

7.5.1 Future Character of Military Medicine

War is recognised to have an enduring nature, but an evolving character (British Army, 2011). In parallel, rational medicine has an enduring nature (to save life, relieve suffering and prevent further harm), but a changing character that is shaped by enhanced scientific understanding, emergent technologies, and both political and social expectations for healthcare.

The *Future Character of Conflict* (UK MoD, 2010) has been described in the context of an environment that is congested, cluttered, contested, connected and constrained. The same lens may be applied to a novel analysis of the *Future Character of Military Medicine* (FCOMM), but the emphasis is unequal and the image is incomplete: to bring clarity to the vision of FCOMM it is proposed the precepts of analysis of the future environment are modified to be ‘confused, complex, constrained, collaborative, contested, connected and congested’ (Figure 7.1).

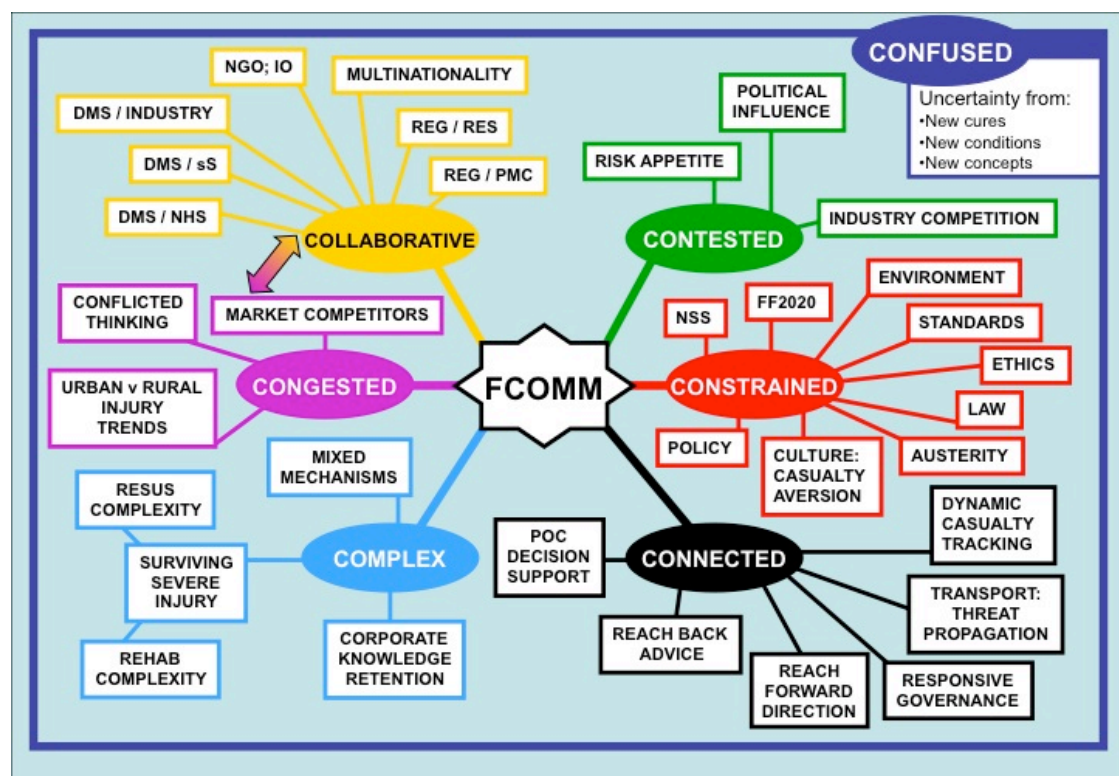


Figure 7.1: The Future Character of Military Medicine

An understanding of FCOMM (**Hodgetts & Findlay, 2012a & 2012b; Hodgetts 2012**) is important if future clinical capability changes are to be focused on predictable operational need and contextualised within what is the accepted evolution of the future character of conflict. Beaty (1997) understood the value of predicting how changes in the external environment (geostrategy, information technology, medical practice) may result in RM2A, but there is no evidence that this forethought was used as a framework to drive capability development. His vision that military medical care on operations up to 2015 would focus on developing 'enhanced first responders, including a more capable combat lifesaver and a team of "brilliant medics" ' (Beaty 1997, p.63) has been realised. However, the prediction that field hospitals would 'do the minimum necessary to keep a soldier alive until he or she can be evacuated...for definitive treatment' (Beaty 1997, p.69) has proven not to withstand the sustained momentum to drive up standards of combat casualty care beyond civilian healthcare norms.

7.6 Future research opportunities

Before turning to the final conclusions of the thesis it is appropriate to consider what principal research opportunities have been identified in the analysis. These are:

1. Understanding whether taught disaster principles match the genuine requirement during an incident;
2. Quantifying the effect of time on clinical outcome within the contemporary combat casualty care system;
3. Measuring the impact of regionalisation of civilian trauma on improvement in outcome, and;
4. Measuring the effectiveness and impact of knowledge transfer from the military trauma system to the civilian trauma system.

8 Conclusions

This thesis set out to determine whether advances in combat casualty care constitute a Revolution in Military Medical Affairs (RM2A) and specifically whether there has been *a radical change in the character or practice of military medicine*. The evidence demonstrates that a revolution can be claimed, within the accepted sentinel criteria—Lambeth’s (1997) criteria for a Revolution in Military Affairs (RMA); Cohen’s (2009) three tests for an RMA, but adapted for an RM2A; and Toffler’s (1993) criteria for a ‘true revolution’. This RM2A is responsible for the unexpected and unprecedented positive outcomes following critical combat injury.

The thesis also set out to qualitatively appraise my contribution to revolutionary change, through prior publication. The range of publications selected demonstrates leadership of this revolutionary process through sustained personal innovation to create concepts, heuristics, guidelines, national and international training programmes and systematic governance of the military trauma system.

The *Homunculus Casualty Theorem* has been proposed in order to evaluate whether developmental effort has been proportional and appropriate to the clinical risks encountered. The theory is largely proven, if only for the pattern of injuries seen within the current Afghanistan campaign. UK Defence has adapted to the Afghanistan homunculus, through changes in combat tactics, body armour, vehicle protective systems and treatment practices to optimise the outcome for a campaign-specific pattern of injuries. A subtly or profoundly different homunculus casualty can be expected for every future campaign. I have been responsible for establishing the adaptive systems for future success—the Joint Theatre Trauma Registry and the Joint Theatre Clinical Case Conference.

Where the *Homunculus Casualty Theorem* shows a failure to match clinical need to systems development is in battlefield analgesia. I undertook an academic review of battlefield analgesia in 2006, publishing recommendations for clinical change (**Hodgetts et al** 2006) from a standard unchanged for 100 years: these were not accepted institutionally. In an academic review of Role 1 capability 6 years later I have stated that ‘Inadequate analgesia at Role 1 is an intolerable capability failing, consistently and objectively identified on operations...The institutional resistance to employing alternative analgesia to intramuscular morphine needs to be overcome’ (**Hodgetts & Findlay** 2012a, p.9). This has generated traction, with change being

accelerated to implement transmucosal fentanyl as a standard Role 1 analgesia option. What this demonstrates is that some change demands persistence and a refusal to compromise. To paraphrase George Bernard Shaw (1903), all progress depends on the unreasonable man.

The conditions for continuing revolution in combat casualty care have endured with the sustained operational tempo, but they are fragile. A decline in casualty numbers on planned cessation of combat operations in Afghanistan in 2014 will predictably dilute the agenda for further change. Heroic operational medicine may need to be reigned-in for high intensity conflict, and may be undeliverable to the same standard in a new early entry operation with a limited medical footprint.

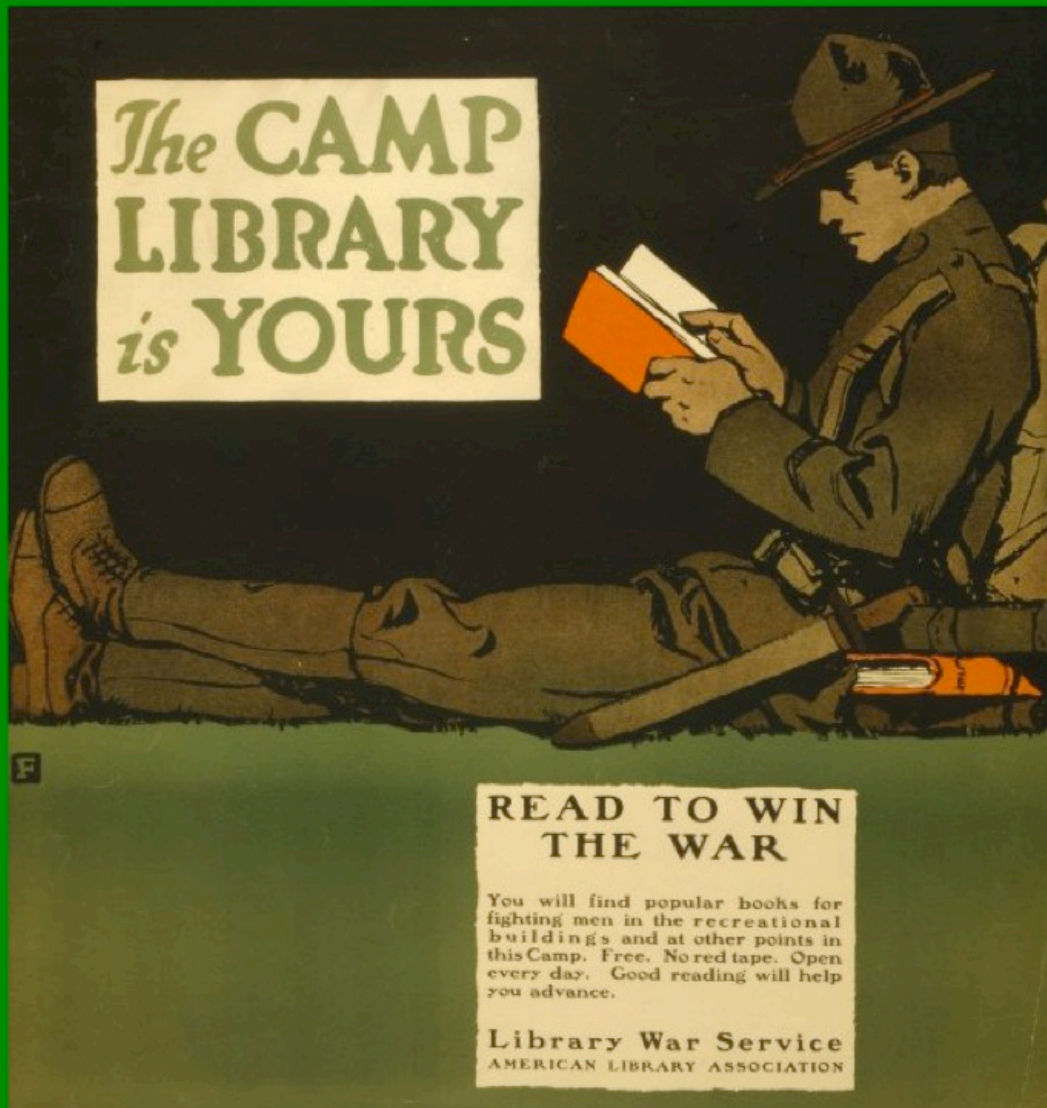
The NHS has demonstrated a repeated failure to transform its trauma services between 1988 and 2007, when presented with evidence from national surgical institutions. The catalyst to begin transformation and regionalise trauma services has been the poor performance reiterated in the NCEPOD (2007) report. The opportunity for future military resilience to generate comparable standards of expeditionary trauma care lies with transferring knowledge to this developing civilian nationwide system of regional trauma centres and, in particular, to the established military-civilian Role 4 partnership in Birmingham. However, the ethical, policy, logistic and economic implications for the NHS adopting the heroic stance on trauma resuscitation cannot be underestimated and are referred to as the 'blowback' from innovation (Lin, 2010).

I have also presented evidence of how to identify and prevent avoidable in-hospital cardiac arrest. Despite best efforts to personally influence change across the NHS through adoption of a nationally distributed educational initiative, the same systemic failure has been proven 10 years later. It is hoped that as NCEPOD has been the catalyst for organisational change across NHS for major trauma (NCEPOD 2007), its report of 2012 on avoidable in-hospital cardiac arrest will provide a parallel stimulus.

The National Clinical Director for Trauma Care for NHS England told the National Audit Office in 2010 that 'the organisation and facilities of Camp Bastion field hospital [Afghanistan] are equivalent to NHS best practice for trauma care' (NAO, 2010, p.16). The National Clinical Director is mistaken. In relation to trauma, the organisation, facilities and outcomes in a British field hospital during an extended campaign now exceed NHS best practice. An obligation rests with the DMS to

effectively transfer organisational learning—but most importantly, for the sake of the sacrifice of our fallen and injured soldiers, an obligation rests with the NHS to overcome the known barriers to innovation adoption to benefit the injured of the future.

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ANNEXES



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Publications for TJ Hodgetts

Only a list of books, book chapters and peer-reviewed papers is included here. Monographs, restricted internal reports, journal letters, case reports, educational videos, and educational DVDs are excluded.

Books & Chapters

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The royalties of this book are donated to military charity

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Military Medical Roles



Role 1

Primary health care, specialised first aid, triage, resuscitation and stabilisation.

Examples: Regimental Aid Post, sick bay afloat.



Role 2

Triage, consultant-led advanced resuscitation, +/- Damage Control Surgery.

Examples: In Role 2 Light Manoeuvre configuration it is effectively a Forward Surgical Team; in Role 2 Enhanced configuration it is effectively a small field hospital with core specialties represented.



Role 3

Comprehensive secondary care provided in the Theatre of Operation. A sophisticated field hospital.

Example: UK Role 3, Camp BASTION, Afghanistan.



Role 4

Specialist and/or prolonged in-patient care, definitive treatment and extended rehabilitation provided in the home nation.

Example: Royal Centre for Defence Medicine, Birmingham.

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Letters of Authority

Lieutenant Colonel RJ Russell RAMC

Major D Willdridge RAMC

Lieutenant Commander S Brodie RN

Squadron Leader J McLeod RAF

Surgeon Commander J Smith RN



Lt Col Robert J Russell
MB BS MRCP(UK) FCEM DipIMC RCSEd MIIM RAMC
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Date: 20 June 2012

City University London
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Dear Sir/Madam

Re: COLONEL TIMOTHY JOHN HODGETTS CBE

Russell R, Hodgetts T, McLeod J, Starkey K, Mahoney P, Harrison K, Bell E. The role of trauma scoring in developing trauma clinical governance in the Defence Medical Services. *Phil Trans Roy Soc B* 2011; 366(1562): 171- 191

I can confirm that Colonel Hodgetts contributed significantly to the genesis of this article.

He was involved in determining the original idea, the structure and editing successive versions in development. In addition, he was the main author for one of the sections within the paper.

Yours faithfully



Ref: LJE/DW

Typed: 22 June 2012

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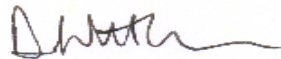
Dear Sir/Madam,

I can confirm that Colonel TJ Hodgetts CBE had extensive and significant involvement in every stage from the initial project planning to the manuscript preparation, of the following academic paper:

Willdrige D, Hodgetts T, Mahoney P, Jarvis L. *The Joint Theatre Clinical Case Conference: clinical governance in action*. JR Army Med Corps 2010; 156(2): 79-83.

If you require any further information, please do not hesitate to contact me.

Yours sincerely,



Major Daniel Willdrige RAMC
Anaesthetics Registrar
Wessex Deanery



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City University London

Date: 14 Jun 12

Sir

I can confirm that Colonel Timothy J Hodgetts was a significant contributor to the Article;

Steven Brodie, Timothy J Hodgetts, Jo Ollerton, Judith McLeod, Paul Lambert, Peter Mahoney. (2007). Tourniquet Use in Combat Trauma: UK Military. *Journal Royal Medical Corps*. 153 (4), p310-313

I have been approached by Col Hodgetts and I can confirm I am content for the article to be used in his PhD by Prior Publication Submission.

Yours Aye

S Brodie
Lt Cdr
SO2 RCM NAHP



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Date: 26 June 2012

PHD BY PRIOR PUBLICATION

I am the first author for the following paper which was published in 2007:

McLeod J, Hodgetts T, Mahoney P. (2007) Combat 'Category A' calls: Evaluating the pre-hospital timelines in a military trauma system. *JR Army Med Corps*; 153(4): 266-268.

I can confirm that Col Hodgetts made a significant contribution to the published paper and I am content for the paper to be used within his thesis for a PhD by Prior Publication.

A handwritten signature in black ink, appearing to read "J D McLeod".

J D McLEOD
Squadron Leader
Aviation Medicine Instructor



Surgeon Commander J E Smith Royal Navy
MBBS MSc MRCP (UK) MFSEM (UK) FCEM

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Our Ref: JS/JCH

Date: 22nd June 2012

To: City University London

Re: Significant contribution to the article entitled OESmith J, Hodgetts T, Mahoney P, Russell R, Davies S, McLeod J. Trauma governance in the UK Defence Medical Services. JR Army Med Corps 2007;153(4): 239-242.¹

I can confirm as first and corresponding author of the above article, that Colonel Timothy Hodgetts CBE made a significant contribution to the manuscript. He had input at all stages, from when the idea for the paper was conceived, through to drafting the initial versions of the manuscript, and editing the final manuscript.

Yours faithfully



Surgeon Commander J E Smith Royal Navy
Consultant in Emergency Medicine



Working in partnership with the Peninsula Medical School
Chairman: Steven Jermy interim Chief Executive: Helen O'Shea



Supporting Papers 1-20

- 1 The Paediatric Triage Tape
- 2 Battlefield first aid: a simple systematic approach for every soldier
- 3 Lessons from the first operational deployment of emergency medicine
- 4 Training for major incidents: evaluation of perceived ability after exposure to a systematic approach
- 5 Incidence, location and reasons for avoidable in-hospital cardiac arrest in district general hospital.
- 6 The identification of risk factors for cardiac arrest and formulation of activation criteria to alert a medical emergency team
- 7 Care of Civilians during Military operations
- 8 Evaluation of clinician attitudes to the implementation of novel haemostatics
- 9 ABC to <CABC>: redefining the military trauma paradigm
- 10 Battlefield Advanced Trauma Life Support (Parts 1, 2 and 3)
- 11 Trauma governance in the UK Defence Medical Services
- 12 Operational Mortality of UK Service Personnel in Iraq and Afghanistan: A One-Year Analysis 2006-7
- 13 Combat "Category A" calls: evaluating the pre-hospital timelines in a military trauma system
- 14 Tourniquet use in combat trauma: UK military experience
- 15 Damage Control Resuscitation
- 16 UK Defence Medical Services guidance for use of recombinant Factor VIIa in the deployed military setting
- 17 Benchmarking the UK military deployed trauma system
- 18 Military Pre-Hospital Care: Why is it different?
- 19 The Joint Theatre Clinical Case Conference (JTCCC): Clinical governance in action
- 20 The role of trauma scoring in developing trauma clinical governance in the Defence Medical Services

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