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An analysis of deaths following trauma in Scotland

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Doctor of Medicine
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Declaration of originality

I declare that the work reported in this thesis, submitted to the University of Edinburgh for the degree of Doctor of Medicine, was originated and performed by me, with the exception of the assistance detailed in the acknowledgements. I declare that data was collected and analysed whilst I was in post as senior registrar in Accident and Emergency in the Royal Infirmary of Edinburgh and research fellow in Forensic Medicine in the University of Edinburgh. I also declare that this thesis was composed by myself and has not been submitted in candidature for any other degree, diploma or professional qualification.

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This thesis is dedicated to my wife and family.

Abstract

The principal objectives of this thesis were to examine how, where and why deaths occur after trauma in Scotland, with a view to seeing how, in future, deaths might be prevented. This investigation comprised a detailed analysis of several thousand trauma deaths, concentrating upon background circumstances of the traumatic episodes, timing of deaths, severity and pattern of injuries sustained, forensic and medicolegal aspects and treatment provided. Data sources included prospectively collected data from the Scottish Trauma Audit Group, Accident and Emergency, Procurator Fiscal and Forensic Medicine units. Injuries were scored and analysed according to the Abbreviated Injury Scale (1990 revision).

The large number of deaths confirmed official figures, demonstrating that road traffic collisions, falls, hangings, drownings, fires and assaults were responsible for 88% of trauma deaths. Analysis of the timing of these deaths in Lothian and Borders regions of Scotland revealed that 76% died before reaching hospital, with the vast majority being either dead when found or having injuries acknowledged to be unsurvivable using the Abbreviated Injury Scale. Findings in south-east Scotland were mirrored elsewhere in Scotland. These findings challenge the previously accepted concept of a trimodal distribution of trauma deaths and indicate that overall, there is a greater potential to reduce the death rate through injury prevention measures rather than through improved prehospital or hospital treatment.

The collected data relating to advanced prehospital care did not prove any objective benefits of such treatment, although research in this area is methodologically difficult. Analysis of hospital care using TRISS methodology demonstrated that the minority of trauma patients treated by Accident and Emergency consultants had a significantly better outcome than the majority treated by junior doctors. This implies that by changing the seniority of staff with responsibility for trauma there may be some potential for improving outcome by improving hospital treatment. Analysis of deaths according to the mechanisms of injury revealed few areas where improved hospital treatment could have prevented large numbers of deaths, although one important exception to this appeared to be deaths amongst pedestrians after road traffic collisions, most of whom died having reached hospital alive.

A national prospective study of 1305 Scottish trauma deaths in 1995 implicated alcohol in causing a large proportion of deaths. Injury prevention measures aimed at reducing the trauma death rate need to focus upon the role of alcohol, taking into account the fact that it is difficult to modify the behaviour of individuals once under the influence of alcohol. The way forward appears to lie with injury prevention measures combining legislation, advances in engineering and technology with community education and health promotion.

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Abbreviations

A&E	=	Accident and Emergency
AAAM	=	Association for the Advancement of Automotive Medicine
AIS	=	Abbreviated Injury Scale
a.m.	=	ante meridiem (before noon)
ASCOT	=	A Severity Characterization of Trauma
BP	=	Blood Pressure
dl	=	decilitre(s)
e.g.	=	exempli gratia (for example)
GCS	=	Glasgow Coma Scale
GP	=	General practitioner
HDU	=	high dependency unit
H.M.	=	Her Majesty's
HMSO	=	Her Majesty's Stationery Office
ICD	=	International Classification of Diseases
i.e.	=	id est (that is)
ISS	=	Injury Severity Score(s)
ITU	=	intensive therapy unit
MAIS	=	maximum Abbreviated Injury Scale score
mg	=	milligrams
min(s)	=	minute(s)
mm	=	millimetres
mmHg	=	millimetres of mercury (pressure)
MTOS	=	Major Trauma Outcome Study
NFS	=	not further specified
NISS	=	New Injury Severity Score
No.	=	number
p.m.	=	post meridiem (after noon)

Ps = Probability of survival (as calculated using TRISS methodology)

RTC = Road traffic collision

RTS = Revised Trauma Score

STAG = Scottish Trauma Audit Group

“TRISS” is an acronym from **T**Rauma score and **I**njury **S**everity **S**core.

UK = United Kingdom

USA = United States of America

yr(s) = year(s)

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Chapter 1 - General introduction

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1.1 View from the stretcher: a patient's perspective

Introduction

What follows is my personal account of a road traffic collision, which was written shortly after recovery and return to work.

My Accident

My accident was my fault. I sustained multiple injuries. Dozing off to sleep I jerked awake to discover bright lights of a fifty ton lorry looming and felt certain I was about to die. An enormous, painful bang followed. With great surprise I found myself to be alive. Alive and awake and no head injury. The air was filled with a choking smell of burning rubber. I checked that all limbs were attached then felt pain in my legs.

My van was a mess. There was no question of trying to get out. The hiss and smell of petrol from the engine on my lap alarmed me. The lorry driver, thankfully unhurt, appeared shouting a (justified) torrent of abuse. He relented when I apologised and explained my predicament. I asked him to get his fire-extinguisher: he helped further by radioing for assistance.

Other vehicles arrived - the first few did not stop, but weaved awkwardly past and carried on. My early thoughts were quite inappropriate. I recall annoyance

at missing excellent ice climbing conditions forecast for the following weekend. Rather dispassionately, I surveyed the damage. My thighs were aching - clearly both femurs were broken. Unfortunately, my seat had buckled so my legs were hanging free, pulling the fractures apart. I found I could help by pulling upwards under my knees. This caused discomfort in my wrist, but I failed to recognise the fracture there. In fact, my clinical assessment was rather disappointing - I diagnosed only two out of eight fractures! Frustratingly, I was unable to use the drip which I carried, since it was out of reach under my seat. As my wait continued I became aware of right-sided pleuritic chest pain and dyspnoea. I could not detect subcutaneous emphysema or tracheal deviation but remained concerned about a pneumothorax.

By now dozens of people were milling around. Police arrived and took full details from me. I asked them to send for the "Flying Squad" from the Teaching Hospital thirty miles away, where I had previously worked. An ambulance arrived. Unfortunately, it did not carry drip sets. The ambulancemen explained that once freed I would be taken to the local District General Hospital. I told them I wanted to go to the larger Teaching Hospital which had more expertise in major trauma. I was told it was "outside their area" and an argument ensued. Thankfully, a policeman intervened saying he would contact a different ambulance crew. A fire-engine arrived, but without "heavy enough" cutting equipment. Another was sent for.

I became thirsty and cold. Things seemed chaotic. I asked again for someone to request the "Flying Squad", but it did not come. It later transpired that my requests never got through.

People wandered about, some smoking, despite the petrol. A second ambulance appeared, this one prepared to take me where I wanted. The first ambulance departed, its driver understandably irritated. Eventually, more firemen arrived and cut me out. They lifted me slowly, but I experienced severe pain as various fractures jostled for position. My contorted legs would not fit into splints, so they were simply supported with pillows.

Once in the ambulance I expected rapid transfer to hospital. I was surprised to be delayed by a "new" policeman who insisted on asking the same questions I had previously answered. Apparently, the policeman from earlier had gone off-duty. I explained, admittedly somewhat profanely, that I believed myself to have a potentially life-threatening combination of severe blood loss and a punctured lung, but it was to no avail. I was furious, but realised the quickest approach would be to answer his questions, which included such gems as "Where were you born?" This surrealistic experience continued languidly as I spelt out "Old Coulsdon" and then had to explain where it was. My transfer was delayed for about ten minutes.

Eventually, the ambulance started moving. I felt every bump through my femurs, but declined Entonox, feeling in a strange way, that I wanted to remain alert and "in control". Although I knew it was ridiculous my thirst became overpowering such that I even found myself asking for water. I got the expected and quite proper answer and became irritated by myself. Soon, I felt very light-headed and wondered if I had reached my limit of compensation for hypovolaemia. Enquiry revealed that this ambulance had been equipped with extra equipment, although the crew were not

specially trained. Whilst travelling, I instructed one ambulanceman on how to arrange a drip set, then stopped the ambulance briefly whilst I inserted a green venflon into my left cephalic vein. I did not feel the needle and was extremely relieved to see the flashback! I ran in a litre of clear fluid before reaching the relative haven of hospital.

Figure 1.1(i) - The result of the collision upon my light van



Figure 1.1(ii) - The result of the collision upon my right femur



“Initial afterthoughts”

My accident taught me some lessons. One has been learnt by others previously: the folly of driving 550 miles after a night on-call. 31st January and 31st July have seen the demise of many doctors travelling between jobs. I believe it is time to stop this unnecessary carnage by a change in the system of job-changeovers.

Following my experience, I carry a fire-extinguisher in my van, although it would have a doubtful impact on a significant fire. I have now administered intravenous fluid at four road traffic accidents whilst "off-duty". I recommend that all doctors carry resuscitation sets in the boots of their vehicles, where they are secure and available for self-administration. I believe all ambulances should be fitted with such equipment, regardless of the crew's expertise, because a doctor is often available.

As a doctor I altered my pre-hospital care in two ways: setting up a drip and changing my destination to a larger hospital. I was, however, unable to get a message through to the "Flying Squad". This underlines the importance of accurate relay of information between the various components of the Emergency Services. Arguments concerning the role of "Flying Squads" continue, but I feel I should add my voice in favour in some unusual respects. Firstly, in addition to commencing resuscitation and administering analgesia to allow splintage, an experienced team could enforce sensible precautions, including the prevention of smoking near petrol. Secondly, outrageous transfer delays, such as those caused by unnecessary and inappropriate (double) collection of useless data might be prevented! Undoubtedly the policeman who enforced my delay believed he was acting correctly. I speculate that because my

injuries were mostly closed he under-estimated the need for urgent treatment. I am concerned that non-medically trained professionals are making important decisions regarding the transfer of seriously injured patients. This problem would not exist with experienced doctors at the scene.

“Later afterthoughts” and outcome

This account of a junior hospital doctor, tired following a night on call, having a serious road traffic collision as a result of falling asleep at the wheel whilst driving to take up a new job, is not an isolated case. I have worked with two other doctors who have also been hospitalised with serious injuries in similar circumstances. Thankfully, there now appears to be a greater awareness of this potential problem, so there is now much more flexibility and consideration given to junior doctors at job changeover times who have to travel long distances to take up new jobs.

The passage of time, my experience whilst working as a team member in the Royal Infirmary of Edinburgh’s “Medic One” flying squad and recent published evidence have combined to slightly alter my views on the value of prehospital care. I remain very positive about the benefits of prehospital trauma care delivered by appropriately trained individuals and still have concerns about unnecessary delays at the scenes of accidents and about poor management of potential secondary dangers such as fires. Certainly, from the patient’s perspective I can fully appreciate the benefit of timely prehospital splintage and analgesia. However, some issues, such as

the benefits of prehospital intravenous fluid administration have become somewhat contentious and are discussed fully in chapter 8.

From a personal perspective, my road traffic collision altered the course of my life significantly. After six months in hospital I progressed via a Zimmer frame to crutches before walking again unaided. By three years I had returned to my previous sporting activities and managed to climb the Matterhorn, which although considered a technically easy climb by most mountaineers, proved to be a considerable personal challenge. I have learnt, albeit rather painfully, how it is possible to make a good functional recovery from orthopaedic injuries - a process aided by the absence of any associated significant head injury. From a career point of view, I was fortunate in that I was helped by two consultant surgeons who supported me through my basic surgical training. However, as a result of my road traffic collision, I found myself drawn towards Accident and Emergency Medicine as a career and developed an interest in the prevention and early management of major trauma. The work contained within this thesis represents a natural progression of this interest.

Figure 1.1(iii) - The Matterhorn viewed from above Zermatt



Figure 1.1(iv) - The Matterhorn summit (right foot in Italy, left foot in Switzerland)



1.2 Trauma deaths - more than a modern epidemic

Perhaps the most widely quoted fact concerning the epidemiology of deaths following trauma is that trauma is the most common cause of death amongst children and adults up to the age of 30 years in the western world (Department of Health, 1992; American College of Surgeons, 1988). Repeated reiteration of this fact is, of course, entirely justified, in order to encourage and force steps to be taken to ensure that this statement no longer be true. Trauma is often (rightly) regarded in terms of it representing a "modern epidemic" (Saadia, 1999), yet this ignores the fact that it has been an "ancient epidemic" too!

At cursory first sight, the causes and background to much of modern trauma would appear to be very different from that of hundreds or thousands of years ago. Certainly, there can be little doubt that the introduction of the motor vehicle at the turn of the last century has dramatically changed the face of serious modern trauma. However, the differences between "ancient" and "modern" trauma are perhaps less than is generally appreciated. It is worth remembering that travel, particularly over long distances, with or without the motor vehicle, has always been associated with certain perils. In the past, instead of using an aeroplane or motor car in order to undertake a long journey, it was often necessary to travel (at least part of the way) by ship. Descriptions of early ships from several thousands of years ago are enough to confirm the potential dangers of sea travel (Wells, 1920). In the past as now, drowning represented a relatively common form of death from trauma. Similarly, fire,

the sister element to water, continues to pose a threat. The terrible destruction and danger to human life of uncontrolled fire has long been recognised, as exemplified in the Great Fire of London in 1666 (Bevan, 1985).

Perhaps the most obvious way in which people died from trauma in the past was as a result of human conflict. "Great" battles in world history, whether on land or at sea, caused huge numbers of deaths - the battle of Agincourt in 1415 resulted in 7500 deaths in a matter of only two or three hours (Jacob, 1947), whereas Sir Francis Drake's defeat of the Spanish Armada in 1588 inflicted more than 1000 Spanish deaths at sea in a single day (Martin & Parker 1988).

In modern times, conflicts between nations continue in Europe as in the rest of the world, but the significant daily problem in the UK is violence between smaller numbers of individuals. Such violence has probably always existed in one form or another. For example, corporal punishment and other forms of violence in the home inflicted upon slaves, servants and children were considered socially acceptable until relatively recently (Scott, 1940).

Another area of concern in the modern technological world is injury and death at the workplace. The construction of modern major buildings and stadia is associated with much unwanted trauma, but these industrial deaths do not reflect a new phenomenon, as descriptions of the toil and manpower losses in the course of building of medieval castles and cathedrals bear out (Foss, 1975; Keates & Hornak, 1980).

Serious injuries and deaths from sporting and recreational activities are also sometimes regarded as a purely modern phenomenon. Certainly, some modern sporting activities exact a considerable toll - for example, the disaster which befell the first team to scale the Matterhorn in the Swiss Alps led by Edward Whymper in 1865 (Whymper, 1871) was followed up in the twentieth century with more than 500 deaths amongst mountaineers attempting to climb the Matterhorn, a statistic not lost on would-be aspirants (Goedeke, 1991). However, serious sporting mishaps have actually occurred throughout history, exemplified perhaps by the death of William II ("Rufus") of England, who was fatally injured whilst hunting deer in the New Forest in southern England in 1100 (Chambers, 1981).

In the past, life expectancy for the majority of the population was relatively short. Trauma was just one of several principal ways by which human life could (and often did) quickly end. Some others, such as infections, whether on a small or massive scale, as in the Black Death of the fourteenth century (Gottfried, 1983) have now diminished (at least in the western world) as major causes of premature death. So, in a modern world where infections can be treated, cancers can be cured and perinatal mortality has been drastically reduced, trauma remains a significant problem and is rightly a target for epidemiologists.

1.3 Trends and government imposed targets

UK targets

The previous UK Government's Secretary of State for Health presented a White Paper in 1992 entitled "The Health of the Nation" which together with its sister document ("Scotland's Health: a challenge to us all"), identified specific key areas to be focused upon for improving health in the UK (Department of Health, 1992, Scottish Home and Health Department, 1992). These five key areas were:

- coronary heart disease and stroke
- cancers
- mental illness
- HIV / AIDS and sexual health
- accidents

As a result of this document, injury in the form of "accidents" and traumatic suicide became a definite focus of attention. The UK government recognised that in addition to trauma being the leading cause of death amongst children aged over one year, adolescents and young adults, it also was responsible for considerable morbidity amongst the general population and accounted for 7% of all National Health Service expenditure (Department of Health, 1992). Particular concern about

trauma death rates amongst certain sections of the population, particularly children and the elderly, resulted in the identification of specific government targets being set out within the framework and spirit of the "Health of the Nation" document:

- "To reduce the death rate for accidents among children aged under 15 by at least 33% by 2005 (from 6.7 per 100,000 population in 1990 to no more than 4.5 per 100,000)".
- "To reduce the death rate for accidents among young people aged 15–24 by at least 25% by 2005 (from 23.2 per 100,000 population in 1990 to no more than 17.4 per 100,000)".
- "To reduce the death rate for accidents among people aged 65 and over by at least 33% by 2005 (from 56.7 per 100,000 population in 1990 to no more than 38 per 100,000)".

When the data were analysed in 1996, early indications were that considerable progress had been made towards achieving these three targets, although cynics might argue that this was simply the result of a continuation of previous trends (Department of Health, 1992; National Audit Office, 1996). In 1999, a new UK government revisited the priority areas for health and the targets set by the previous administration. In a statement which might be construed as "typically political", the new government claimed to "reject the previous Government's scattergun targets" and

replaced them with "tougher but attainable targets in priority areas" (Secretary of State for Health, 1999).

Recognition of the continuing problem presented by injury resulted in "accidents" continuing to feature as one of four priority areas which were identified as:

- cancer
- coronary heart disease and stroke
- accidents
- mental illness

The revised new target set by the government for "accidents" was to reduce the overall death rate by 20% between 1997 and 2010 (Secretary of State for Health, 1999). Some of the initiatives listed by the government as being useful in helping to achieve this target (such as the statement that "frontline ambulances now have a fully qualified paramedic") remain of questionable value (see chapter 8.1), but at least underline the government's commitment to this area (Secretary of State for Health, 1999). Interestingly, whilst policy-makers may try to take credit for reductions in the death rates from injury by the changes which they have put in place, changing social trends totally divorced from such policies may actually be responsible. For example, evidence suggests that the decrease in death rate among child pedestrians and cyclists is actually a reflection of the significant recent decreases in walking and

cycling among children (in favour of being transported more frequently by motor car), rather than by walking and cycling becoming safer for children (DiGuisseppi et al., 1997). Ironically, these changes may to some extent be counter-productive in that improvements in one priority area (e.g. reduced child travel deaths) may adversely affect another area (e.g. reduced exercise may predispose to an increase in coronary heart disease).

Targets in the US

The United States Department of Health has identified "Injury and violence prevention" as a focus area in its "Healthy People 2010" document which contains the nation's health goals for the next decade (United States Department of Health and Human Services, 2000). Unlike its UK equivalents, this document fails to concentrate upon a handful of key areas, but instead covers a wide array of health problems. Despite the acknowledged role of injury in the USA (Committee on Trauma Research, 1985), this is only one of 28 "focus areas" listed in the "Healthy People 2010" document, which as a result has been criticised as being too exhaustive and unwieldy (Davis, 2000).

1.4 Analytical approaches used in this and previous work

The aim of the work in this thesis was to study deaths following trauma in Scotland, with a view to reaching conclusions as to how in future such deaths might be prevented. The approach used in this thesis differs from that used in previous work. Previous studies have either focused upon cohorts of injured patients who reach hospital alive, but die later (hospital deaths) or upon those patients referred to the H.M. Coroner / Procurator Fiscal (or legal equivalent) and who subsequently undergo post-mortem examination. Neither of these approaches when used on its own is able to provide an epidemiologically complete picture of deaths from trauma in a particular region. Hospital-based studies inevitably fail to include those individuals who die before reaching hospital. Similarly, studies based solely upon an examination of coroner's records (e.g. the study by Baker et al., published in 1980, upon which the widely accepted "trimodal distribution of trauma deaths" is based - see chapter 3.1) may not include those cases which are never referred to or are never thoroughly investigated by the coroner - these cases tend to include patients who die in an "expected" fashion relatively late in hospital (days or weeks) after sustaining trauma. Also, in some centres, the instruction by a coroner to a pathologist to perform a post-mortem examination may not always result in a detailed autopsy. A low autopsy rate may reflect various local factors which include: legal, cultural, financial and logistical factors.

The data analysed within this thesis combined three key elements which enabled an epidemiologically complete and fully comprehensive picture of traumatic deaths to be obtained:

- a prospective study and collection of demographic and clinical data on all patients admitted to hospital with serious injury (as defined according to UK Major Trauma Outcome Study) by the Scottish Trauma Audit Group (STAG) enabling TRISS analysis, and ensuring identification of all hospital deaths following trauma (see chapter 2.6 and 2.7).
- a policy of investigation of all traumatic deaths by the Procurator Fiscal which included the preparation of a detailed police report of the exact circumstances (see chapter 2.2 and 2.3) and the instruction of a crown pathologist to perform a post-mortem examination in all cases.
- a system whereby all those cases referred for post-mortem examination were subjected to detailed autopsy according to a standardised procedure enabling injuries to be recorded and accurately scored using the Abbreviated Injury Scale (see chapter 2.8).

Chapter 2 - Methodology

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2.1 Introduction to methodology in this thesis

As explained in chapter 1, the studies which comprise this thesis required collaboration between a variety of different organisations at a national level, most critically, A&E departments, Forensic Medicine Units, STAG and the Scottish Office. Information was gathered prospectively from all these sources and also from the Registrar General of Births, Deaths and Marriages, forensic laboratories, the police and ambulance services. The way in which the data was collected and analysed is outlined in subsequent sections of this chapter.

The vast majority of the data were extracted from relevant sources by a single person (the author), allowing their recording in a standard fashion using a standardised proforma. This proforma comprises four sections:

- basic information (age and sex)
- information about timing of injury, arrival at hospital and death
- background details concerning how each injury occurred
- a detailed list of injuries sustained

Most of the data obtained for the 1305 deaths comprising the 1995 national Scottish trauma deaths study (chapter 7.2) were extracted by the author, the remainder were extracted by five other investigators. These data were scrutinised and entered onto a database by the author and where necessary, data were checked by

referral back to the original sources. The bulk of the work contained within this thesis refers to a database of more than 2000 trauma deaths in Scotland. The injury scoring of the vast majority of these deaths was performed according to the Abbreviated Injury Scale, 1990 revision (chapter 2.7) by one of two individuals (one being the author) and was checked by another. Sections of this thesis which rely heavily upon national STAG data (e.g. chapter 9.3) analyse data which have been collected by a large number of different individuals, and which have been subjected to the standard rigorous scrutiny and checks employed by STAG, allowing all hospital deaths to be identified and data entered onto a database with a high degree of accuracy (see chapter 2.6).

Some of the data collected were entered onto a database allowing analyses using the Statistical Package for Social Services for Windows version 6 (Statistical Package for Social Services, 1996). A number of the complex statistical analyses (particularly those involving TRISS methodology using national coefficients) required statistical assistance from the statistician at STAG (Wyatt, 1996).

2.2 Legal procedure following trauma deaths in

Scotland

Standard procedure dictates that all deaths following trauma in Scotland are referred to the Procurator Fiscal, the only legal official with the common law jurisdiction for the investigation of sudden or violent deaths. The Procurator Fiscal is particularly concerned with the following:

- to gather information which may assist in the prosecution of individual(s) responsible for causing the deaths of others (e.g. culpable homicide, murder, deaths caused by reckless driving, industrial accidents).
- to investigate deaths which are, at first sight, apparently unintentional (“accidental”) or suicidal in nature, in order to confirm that there is no evidence to suggest foul play, and to confirm that there is no culpability of any party or group.
- to investigate deaths occurring at work, in order to ensure that correct safety procedures were followed, and if they were, to consider whether these procedures could benefit from strengthening or alteration. In all such cases, investigation of such deaths will take the form of a Fatal Accident Inquiry as a mandatory requirement in accordance with statute.
- to maintain accurate death statistics.

Information is collected by police officers on the circumstances surrounding each death following trauma. The police will interview eyewitnesses, family, work-mates, the general practitioner of the deceased and hospital doctors involved in his / her ultimate treatment. This information is summarised in a report for the Procurator Fiscal. Usually, only those police officers trained specifically for such tasks are asked to collate this information and report to the Procurator Fiscal. On occasions, particularly if there is any suspicion of any foul play, a forensic specialist may be called upon to examine the scene of death soon after the body is found. The vast majority of cases of traumatic death undergo autopsy on the instructions of the Procurator Fiscal, enabling death certificates to be issued by the crown-instructed pathologists. In certain cases, on the instructions of the Procurator Fiscal, the autopsy dissection is carried out jointly by two pathologists.

2.3 Police reports on deaths following trauma

The reports provided by the police for the Procurator Fiscal following traumatic death are comprehensive and always run to several pages. The reports contain detailed information, allowing an insight into the circumstances leading up to and causing each death. The patient is followed through any medical treatment which he / she received prior to death by recording information obtained from medical staff treating the now-deceased. They also include statements from witnesses and others involved, together with relevant social, medical and psychiatric background information.

In some cases, including homicides and industrial deaths, the reports prepared are very extensive and include evidence from independent experts, which may include Inspectors from the Health and Safety Executive. Fire deaths are investigated by experts from the Fire Service who are particularly skilled at determining the source and cause of fires (Hinkley & Williams, 1986; Pinorini et al., 1994; Berrett & Candy, 1998). Similarly, deaths following road traffic collisions are investigated by police experts trained in "Accident Investigation" who aim to determine how collisions occurred and who, if anyone, was to blame. Vehicles are inspected very thoroughly, on occasions, with the assistance of a mechanical engineer specialising in this area. It is possible, by an examination of the scene of a collision (including the taking of measurements such as the position, length and extent of skid marks), together with an

examination of relevant vehicles (and the extent of damage / deformation), to estimate with a reasonable degree of certainty, the speeds of vehicles involved (Harms, 1993).

In those instances where the death is due to injuries inflicted on the deceased during an assault, various witnesses are interviewed, including any accused or suspected person. Tape recordings and transcripts of these investigations are made. Any objects which are suspected of having been used as weapons are kept and submitted for forensic scientific examination in police laboratories.

2.4 Registrar General data

The General Register Office for Scotland is a government department headed by the Registrar General for Scotland. The department has been in existence since it was established by an Act of Parliament in 1854. The principal functions of the Registrar General for Scotland may be summarised as follows:

- to register “vital events”, comprising births, deaths, marriages, divorces and adoptions, and to produce and publish this data for the benefit of both the government and the public.
- to undertake periodic population censuses, and to publish the results obtained from these.
- to store and preserve public records, yet making them easily available to the public (thereby, for example, assisting the work of genealogists).
- to maintain the National Health Service Central Register of patients for the Scottish Office.

In performing these functions, the Registrar General of Births, Deaths and Marriages for Scotland produces an annual report, listing the numbers of deaths according to cause, age and sex (Registrar General for Scotland, 1996). The data held by the Registrar General is partly based upon causes of death as listed on death certificates. The accuracy of the causes of death as listed on death certificates has

been questioned, particularly as far as deaths in hospital are concerned (Squires & Busuttill, 1995a; Nicholl, 1999). For example, an elderly person admitted to hospital with injuries sustained during a fall and who dies later in hospital of bronchopneumonia (which was itself the result of immobility due to injury), may have the death simply ascribed to infection, or more accurately, to infection secondary to trauma.

In addition, the Registrar General holds information regarding the manner of death (e.g. accidental, suicidal), which originates from a variety of sources. Some limitations of this system and official statistics have also been reported, resulting in a certain degree of inaccuracy (Cooper & Milroy, 1995; Sampson & Ruttly, 1999; Squires et al., 1999). This problem is not unique to the Registrar General system in the UK and has also been reported elsewhere (Jonasson et al., 1999). For suicides in particular, it is acknowledged that there may be significant under-reporting because the suicidal nature of the death has been concealed either by the deceased or by family members (Rosenberg et al., 1988; Davis, 1999). However, having acknowledged the limitations outlined above, the data held by the Registrar General was useful in this study in serving as a cross-check to ensure completeness of data capture.

2.5 Prehospital data: ambulance reports

Paramedics and ambulance crews of the Scottish Ambulance Service who respond to emergency calls throughout Scotland record data on a standard nationally-adopted "Patient Report Form". The form is completed by the paramedics and ambulance crews in triplicate, such that once completed, one copy is retained by the hospital receiving the patient and the others are retained by the Ambulance Service. Although used for patients with all sorts of medical conditions in addition to those who have sustained trauma, the Patient Report Forms contain much clinically useful data, which is summarised in table 2.5A (Wyatt et al., 1999a).

Table 2.5A - Prehospital ambulance crew data

Prehospital ambulance data collected by the Patient Report Form
--

- | |
|---|
| <ul style="list-style-type: none">• basic patient details (name, age, sex, etc.)• location of incident causing injury• mechanism of injury• times of: 999 call, arrival on scene, left scene, arrival at hospital• initial and subsequent observations (pulse, BP, respiratory rate, GCS, etc.)• nature and time of prehospital treatment (e.g. splints, intravenous fluid, analgesia)• a subjective impression of severity of overall injury |
|---|

The Patient Report Forms have anatomical drawings which allow paramedics and ambulance crews to summarise diagrammatically a patient's injuries. In addition, there is space for free text to allow details of the background to an injury to be recorded. An example of the typical information recorded is shown in table 2.5B.

The Patient Report Forms acted as a useful source of additional prehospital information in the studies described within this thesis. They served to confirm or question the results of the police investigations after death and provided information regarding the physiological state of the patient at the scene on arrival of the ambulance and in particular, whether or not the patient was showing any signs of life at that time.

Table 2.5B - Example of clinical details recorded by paramedic

Motorcyclist, not wearing a helmet, seen to lose control at high speed on a bend. Thrown off bike over hedge into a field. Unconscious on our arrival, smelling of alcohol, with obvious facial injuries and partially obstructed airway. Responded to initial measures as described above.

2.6 Hospital data: Scottish Trauma Audit Group

Background and structure

The Scottish Trauma Audit Group (STAG) was established in 1991 to prospectively collect data on the management of major trauma in four teaching hospitals in Scotland, in response to deficiencies in the management of major trauma which were identified in retrospective studies (Anderson et al., 1988; Royal College of Surgeons of England, 1988; Yates, 1988; Court-Brown, 1989). Initial funding comprised a three year grant from the Clinical Resource and Audit Group of the Scottish Office, which enabled the rapid development of the audit infrastructure.

The expansion of STAG was in part due to the agreement in 1994 between all Health Board General Managers in Scotland that STAG should be adopted nationally. As a result, STAG now prospectively collects data on all patients presenting to hospital following trauma in 25 out of the 27 hospitals receiving trauma in Scotland - see table 2.6A. The two hospitals which receive trauma, but which do not currently collect data for STAG are both relatively small (Dr Gray's Hospital, Elgin and Lorn and Islands District General Hospital, Oban), together seeing less than 20,000 new A&E patients per year (British Association for Accident and Emergency Medicine, 1999). In addition, seriously injured patients presenting to these two hospitals tend to be transferred to larger regional hospitals (usually either Aberdeen Royal Infirmary or Southern General Hospital in Glasgow). There are a number of

general practitioner led “cottage” hospitals and minor injury units scattered throughout Scotland (particularly in more remote rural areas such as the Islands of Arran, Shetland and Skye), but again these hospitals transfer seriously injured patients for definitive management to larger centres (British Association for Accident and Emergency Medicine, 1999).

Table 2.6A - Hospitals participating in STAG listed by region

Hospital by region	Number of A&E new attendances per year
<u>South-West</u>	
Crosshouse Hospital	55,599
Dumfries and Galloway Royal Infirmary	26,000
Glasgow Royal Infirmary	68,000
Glasgow Southern General Hospital	44,602
Glasgow Stobhill Hospital	45,000
Glasgow Victoria Infirmary	71,529
Glasgow Western Infirmary	53,000
Hairmyres Hospital	36,132
Inverclyde Hospital	34,000
Law Hospital	43,000
Monklands Hospital	62,073
Royal Alexandra Hospital, Paisley	55,000
Vale of Leven Hospital	19,832
<u>South-East</u>	
Borders General Hospital	11,598
Royal Infirmary of Edinburgh	92,000
St John's Hospital, Livingston	37,769
<u>Central and East</u>	
Falkirk and District Royal Infirmary	37,000
Ninewells Hospital	56,000
Perth Royal Infirmary	24,891
Queen Margaret Hospital, Dunfermline	28,933
Stirling Hospital	32,500
Victoria Hospital, Kirkcaldy	35,265
<u>North and Highlands</u>	
Aberdeen Royal Infirmary	51,205
Belford Hospital, Fort William	7,650
Raigmore Hospital, Inverness	23,428

STAG is currently funded to a total of £435,000 per year, comprising £234,000 of central funding and £201,000 local funding, resulting in the current average cost of £58 per patient enrolled in the audit. STAG employs 33 staff as outlined in table 2.6B. In addition to the individuals paid to work for STAG, there are (unpaid) elected medical representatives in each of the four regions of Scotland (south-west, south-east, central, north-east) who work with STAG in regional groups to effect change and improve regional trauma care. These representatives include: regional medical directors (one for each region), local medical directors (one for each hospital collecting data - usually consultants in A&E) and consultants from orthopaedics, neurosurgery, anaesthetics, intensive care, general surgery, vascular surgery and radiology.

Table 2.6B - Summary of STAG employees

Title	Role	Number of staff
National co-ordinator	Overall control for the project	1
Medical chairman	Helps “front” the project and effect change	1
Regional co-ordinators	To co-ordinate STAG in each region	4
Quality assurance manager	To check data quality and answer queries	1
Statistician	Data analysis and assist with research	1
Secretary	Secretarial assistance in the central office	1
Local audit co-ordinators	Responsible for local data collection	24
	TOTAL	33

Data collection

The principal task of the local audit co-ordinators is to work in hospitals which receive trauma and to ensure firstly that appropriate patients presenting with trauma are identified and secondly, that all relevant data is collected on those individuals. Data are analysed according to TRISS methodology and therefore the “standard” entry and exclusion criteria of the Major Trauma Outcome Study are used, as shown in table 2.6C (Champion et al., 1990a; Yates et al., 1992). The most essential element to the work of STAG is the complete collection of data in a prospective fashion (table 2.6D).

Table 2.6C - Entry criteria for the Major Trauma Outcome Study

Entry criteria:

Trauma patients who:

- are admitted for three days or more
- are managed in intensive care
- are transferred to or from the contributing centre
- die as a result of injury

Exclusion criteria:

- patients aged over 65 years with isolated fractured neck of femur or pubic ramus
- children aged under 13 years
- patients who are declared “dead on arrival” at hospital

Table 2.6D - Basic data collected by STAG

Standard STAG data collection

- type and mechanism of injury (e.g. blunt injury, RTC - motorcyclist)
- profile of anatomical injuries on presentation, during stay and at autopsy
- physiological profile on presentation (GCS, systolic BP, respiratory rate)
- times / days of presentation (in-hours, out-of-hours; weekday, weekend)
- patient triage (immediate resuscitation, very urgent, urgent, standard)
- length of time in A&E (time before being seen, time in A&E)
- seniority of medical staff in A&E (consultant, registrar, senior house officer)
- destination after A&E (theatre, ward, intensive care unit)
- time to theatre
- seniority of surgeons / anaesthetists (consultant, registrar, senior house officer)
- type of operation (e.g. laparotomy / splenectomy; internal fixation of fractures)
- time to computed tomography scanning
- patient transfer data
- use of intensive care / high dependency facilities
- duration of stay
- outcome (discharged alive, alive in hospital at 3 months, or died)

Data processing and analysis

In addition to collecting the data as outlined earlier, the local audit co-ordinators, together with the regional co-ordinators, are responsible for regularly checking completeness and accuracy of the data. The use of dedicated individuals to prospectively collect data has resulted in STAG achieving a high level of completeness of data: physiological data of injured patients on presentation to hospital is more than 90% complete and all deaths are identified (i.e. 100% complete). Local audit co-ordinators are trained to score injuries according to the Abbreviated Injury Scale (AIS), 1990 revision, as described in chapter 2.7 (Association for the Advancement of Automotive Medicine, 1990). All patient proformas are checked by the quality assurance manager, who also acts to assist with queries about scoring of individual injuries. Data entry onto a computer database is sub-contracted to a specialised data entry company where dual data entry is undertaken and subsequent key-stroke error checks have demonstrated a high degree of accuracy.

Analysis of data includes the use of TRISS methodology (described in chapter 2.7), generating “W” statistics for each centre according to the type of injury. This outcome data, together with basic data (e.g. number of trauma patients seen, mechanisms of injury, seniority of doctors involved) is fed back twice yearly to all contributing hospitals. Additional collection and analysis of data is performed in relation to the annual STAG national conference, specific research projects or when the initial data suggest that there are deficiencies in trauma care which require to be

investigated in order to allow improvements (thereby closing the audit loop). For example, data suggested that there was a significant difference between the trauma care delivered to patients with penetrating trauma between two major Scottish teaching hospitals with similar resources. This was investigated by detailed analysis of existing data and collection and analysis of additional data (including anonymised peer review of hospital case records), from which ways of improving trauma care were identified (Nichol et al., 1998).

2.7 Quantifying injury and predicting outcome after trauma: Abbreviated Injury Scale, Injury Severity Score and TRISS

Introduction

The Abbreviated Injury Scale (AIS) was initially developed in an attempt to assist research into and investigation of injuries sustained in road traffic collisions (Committee on Medical Aspects of Automotive Safety, 1971). The AIS scoring system and its derived Injury Severity Score (ISS) for quantifying anatomical injury are now well established and have been used for many years to assist study of the epidemiology and management of trauma (Wisner, 1992). The basis of the AIS is to allocate specific codes to specific injuries and also a “score” of severity comprising an integer between 1 and 6 (see table 2.7A).

The AIS which was first published in 1971 was devised by a collaborative team comprising members from the American Association for Automotive Medicine (AAAM), the Society of Automotive Engineers and the American Medical Association accidents (Committee on Medical Aspects of Automotive Safety, 1971). Since the first edition, the AIS has been revised and updated on several occasions, in order to broaden applicability to include other forms of trauma, including penetrating injury, electrical injury, hypothermia, burns and smoke inhalation (Petrucci et al.,

1981; Association for the Advancement of Automotive Medicine, 1990). Additionally, the latest (1990) revision of AIS incorporates some changes in an attempt to more accurately code and score the injuries sustained by young children, as compared to adults (Association for the Advancement of Automotive Medicine, 1990).

For the multiply injured patient, analysis and coding of each injury inevitably generates a large number of individual injury scores. Soon after the first publication of the AIS, it was recognised that in order to obtain a score which would accurately reflect the severity of all injuries, simply taking the highest or Maximum AIS (MAIS) was insufficient (Baker et al., 1974). Instead, in 1974, Baker developed the concept of a “whole body score” or Injury Severity Score (ISS), derived from the three highest individual AIS scores in different body regions (see below) (Baker et al., 1974). The ISS is now the accepted standard for trauma scoring, and is used in research and in both regional and national review of trauma care all over the world (Krischer, 1976; Stoner et al., 1977; Trunkey et al., 1983; MacKenzie, 1984; Yates, 1990; Wardrope, 1992; Wisner, 1992).

In order to compare patients’ hospital presentation with their outcome (measured in terms of survival or death), a method named the TRISS method was developed, using the AIS as the means of scoring anatomical injury (Champion et al., 1981; Boyd et al., 1987). By using data from thousands of injured patients, TRISS methodology enables predicted probabilities of survival to be calculated and allows the identification of “unexpected deaths” and “unexpected survivors” (as described

below), thus facilitating evaluation of trauma care (Champion et al., 1981; Boyd et al., 1987; Cottington et al., 1989; Champion et al., 1990a; Guirguis et al., 1990; Gillott et al., 1992; Karmy-Jones et al., 1992; Yates et al., 1992; Burdett-Smith et al., 1995; Cameron et al., 1995; Regel et al., 1995; STAG 1995; Lane et al., 1996; Nicholl & Turner, 1997).

The Abbreviated Injury Scale

The AIS code book (1990 revision) contains detailed descriptions of more than 2000 injuries. Each injury has been allocated a unique seven digit code number. The last digit of each code follows a decimal point and consists of an integer between 1 and 6. This last digit is the AIS score given to that injury. The AIS attributes a score between 1 and 6 to each individual injury, as follows:

AIS 1 = “minor” injury

AIS 2 = “moderate” injury

AIS 3 = “serious” injury

AIS 4 = “severe” injury

AIS 5 = “critical” injury

AIS 6 = “fatal” injury

In order to correctly code (and thus score) an injury, it is first necessary to ensure that the data sources (comprising clinical case notes and/or autopsy reports) record injuries accurately and in detail. Insufficient details may lead to the severity of an injury being significantly under-estimated and inadvertently under-scored. For example, if it is recorded that a patient simply has “rib fractures”, this scores “2”, whereas if the exact number and location are recorded, this may score much higher (see table 2.7A). This is particularly important with certain specific injuries, such as those involving the spinal cord. Similarly, accurate trauma scoring using the AIS requires training and a strict approach, in order to produce consistent results and avoid inter-observer error (Zoltie et al., 1993).

Table 2.7A - AIS coding of “rib cage” injuries, demonstrating the need for detailed and accurate data

Injury description	AIS code	AIS score
Rib cage injury - NFS	450299.1	1
Rib cage contusion	450202.1	1
Rib fracture - NFS	450210.1	1
1 rib fracture	450212.1	1
1 rib fracture with haemo- /pneumothorax	450214.3	3
2–3 rib fractures at any location, or multiple fractures of a single rib, with stable chest or NFS	450220.2	2
2–3 rib fractures with haemo- /pneumothorax	450222.3	3
>3 rib fractures on 1 side and ≤3 on the other, with a stable chest or NFS	450230.3	3
>3 rib fractures on 1 side and ≤3 on the other, with haemo- /pneumothorax	450232.4	4
>3 ribs on both sides, with stable chest or NFS	450240.4	4
>3 rib fractures on both sides with haemo- /pneumothorax	450242.5	5
open/displaced/comminuted fracture of ≥1 rib	450250.3	3
open/displaced/comminuted fracture of ≥1 rib with haemo- /pneumothorax	450252.4	4
flail chest without lung contusion	450262.3	3
flail chest with lung contusion	450264.4	4
flail chest (unstable chest wall) bilaterally	450266.5	5
flail chest in a patient aged <15 years old	450268.5	5

[NFS = “not further specified”. This code and associated score is allocated when details of an injury are vague or incomplete. In this situation, the score attributed to an injury may be a considerable under-estimate (see text).]

Injury Severity Score

The ISS is designed to reflect whole body injury. It was developed from a mathematical analysis of thousands of injured patients (Baker et al., 1974). To calculate the ISS from an array of AIS scores for a patient, the three highest AIS scores in different body regions are squared then added together. ISS considers the body to comprise six regions as follows:

- 1 Head / neck
- 2 Face
- 3 Chest
- 4 Abdominal or pelvic contents
- 5 Extremities or pelvic girdle
- 6 External (skin)

Possible ISS scores range from one to 75. The highest score of 75 may be achieved by a patient having a “critical” injury of AIS score of five in three different body regions (in this case, $ISS = 5^2 + 5^2 + 5^2 = 75$). In addition, any patient with an AIS score of six (considered unsurvivable) is automatically given an ISS of 75. An example of calculating the ISS is shown in table 2.7B

Table 2.7B - Example of a multiply injured patient

Injury description	AIS score	Body region
Closed linear undisplaced temporal skull fracture	2	head/neck
Bilateral pulmonary contusions	4	chest
Major aortic arch rupture at its root	5	chest
Minor (superficial) mesenteric contusion	2	abdomen
Massive splenic rupture with hilar disruption	5	abdomen
Multiple widespread superficial abrasions	1	external

$$\text{ISS} = (5)^2 + (5)^2 + (2)^2 = 54$$

In the example shown, the three injuries contributing to the ISS are the aortic injury, the splenic injury and the skull fracture. The other injuries make no contribution. The ISS system is therefore open to criticism on the grounds that it fails to take account of all the injuries (e.g. any second or subsequent (lesser) injury within the same body region). In practice, however, the system works well and demonstrates good correlation with outcome in terms of survival or death. Studies have shown that patients who reach hospital alive with ISS scores of greater than 15 have a risk of death of more than 10% (Champion et al., 1990a; Yates et al., 1992). The accepted definition of major trauma, both in clinical practice and in research is therefore an ISS of greater than 15.

Although ISS correlates well with mortality, it is important to realise that it is a non-linear scoring system and also that some scores (e.g. 7, 15, 67) are impossible to attain. Thus, when analysing cohorts of patients, it is more statistically correct to use a median value than a mean.

Predicting probability of survival (Ps)

The ISS has been validated as a good measure of anatomical injury, in terms of actual damage and physical disruption to body tissues (Baker et al., 1974; Baker & O'Neill, 1976). However, in order to most effectively evaluate the likely effect of a set of injuries on a particular patient, in terms of whether he or she is likely to survive having reached hospital, two other important factors need to be taken into

account. These factors are the patient's age and physiological derangement (as defined below) on arrival at hospital, irrespective of any prehospital intervention. Combining the ISS with age and physiological derangement by a method known as "TRISS" methodology allows a probability of survival to be calculated for any patient (Champion et al, 1981; Boyd et al., 1987).

TRISS methodology is mathematically rather complex and therefore usually remains within the domain of statisticians. Physiological derangement is measured by the "Revised Trauma Score" (RTS). The RTS is derived and adapted from the "Trauma Score", and has been validated for use in TRISS methodology (Boyd et al., 1987; Champion, 1989). The RTS is based upon three physiological variables at hospital presentation: the respiratory rate, the systolic blood pressure and the Glasgow Coma Scale (GCS). "Coded values" are attributed to each of these variables, to which a weighting factor is applied prior to the scores being added to yield the RTS (see table 2.7C). The weighting factors applied to each of the three physiological variables in the RTS reflects their relative importance in predicting outcome after trauma. The weighting factors were mathematically derived using regression analysis of data which was collected from more than 28,000 patients (Champion et al., 1989).

Within the field of intensive care medicine, alternative scoring systems have been developed to help to predict and compare outcome based upon physiological derangement and chronic illness. These systems include APACHE (acute physiology and chronic health evaluation) and subsequent modifications, APACHE II and III

(Gunning & Rowan, 1999). Although the APACHE systems enable comparisons to be made between trauma and non-trauma patients, they are not in widespread use for the evaluation of trauma.

Table 2.7C - The Revised Trauma Score (RTS)

Physiological variable	Coded value	Multiplying ("weighting") factor	Score
Glasgow Coma Scale			
13–15	4		
9–12	3		
6–8	2		
4–5	1		
3	0	0.9368	"x"
Systolic blood pressure (mmHg)			
>89	4		
76–89	3		
50–75	2		
1–49	1		
0	0	0.7326	"y"
Respiratory rate (breaths per minute)			
10–29	4		
>29	3		
6–9	2		
1–5	1		
0	0	0.2908	"z"
Revised Trauma Score = "x" + "y" + "z"			

Once a patient's RTS has been calculated, his or her probability of survival can be calculated using the equation:

$$\text{Probability of survival (Ps)} = 1/(1+e^{-b})$$

where "e" is the natural logarithm and $b = b_0 + b_1(\text{RTS}) + b_2(\text{ISS}) + b_3(\text{A})$

"A" is a weighting factor to allow for the age of the patient.

b_0, b_1, b_2, b_3 are weighted coefficients which differ according to whether the patient has sustained blunt or penetrating trauma. The coefficients are derived from Walker-Duncan regression analysis of data from tens of thousands of trauma patients - these coefficients vary according to which population the patient is being compared to (Champion et al., 1990a; Yates et al., 1992). Thus, for example, a patient with a certain ISS, RTS and age would be predicted to have a different probability of survival according to whether he or she was being treated in the USA or the UK, since the levels of trauma care differs between the two countries (Champion et al., 1990a; Yates et al., 1992).

Example of a calculation of probability of survival (Ps):

Suppose the patient with an ISS of 54 in the example given above was a 26 year old female pedestrian knocked down by a bus and that when she presented to hospital she had a Glasgow Coma Scale of 14/15, a systolic blood pressure of 136 mmHg and a respiratory rate of 30 breaths per minute. Her RTS is thus 7.55, allowing her probability of survival to be calculated using the following UK coefficients:

$$b_0 = 0.945$$

$$b_1 = 0.642$$

$$b_2 = -0.122$$

$$b_3 = -1.866$$

$$A = 0$$

Thus, $b = 0.945 + (0.642 \times 7.55) + (-0.122 \times 54) + (-1.866 \times 0) = -0.7959$

$$Ps = 1/(1+e^{0.7959}) = 0.31$$

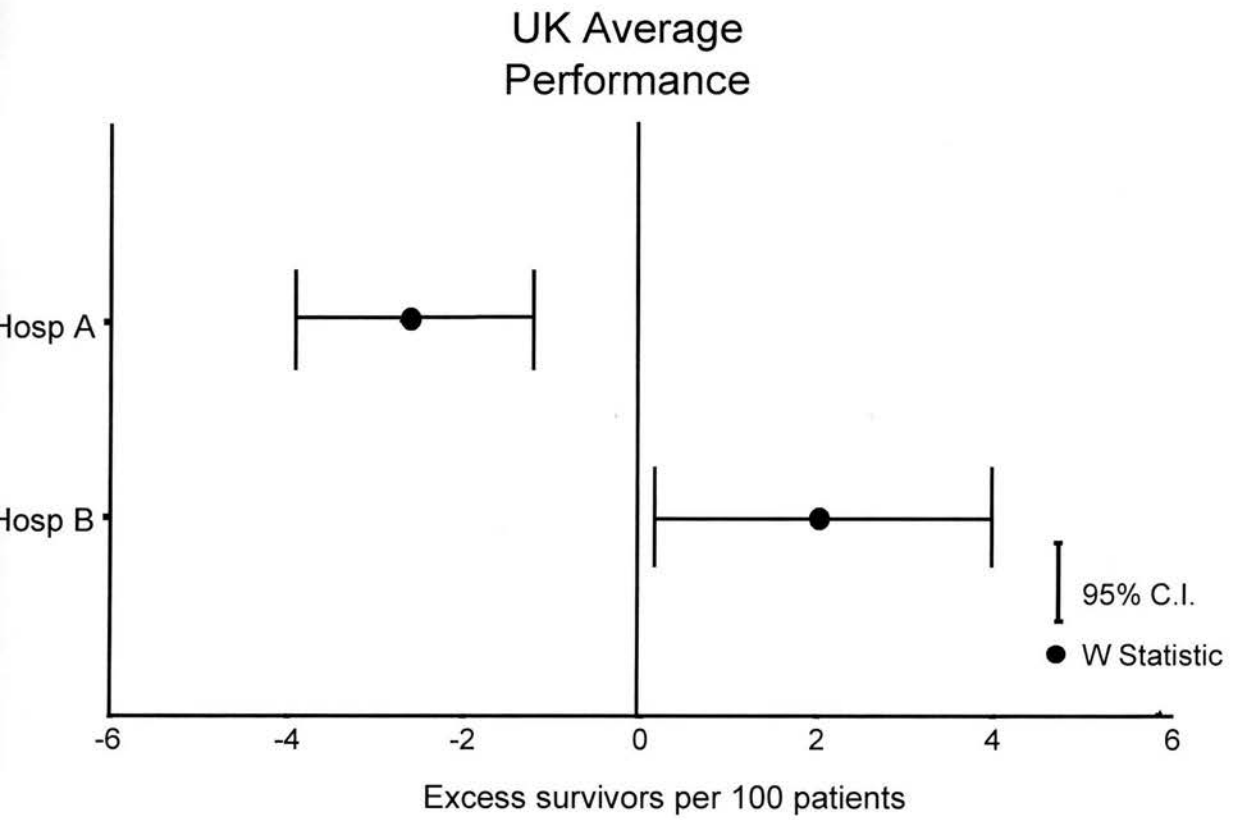
In other words, it would be predicted that this woman would have a 0.31 x 100% (=31%) chance of surviving this injury in the UK. Patients who survive with a Ps of less than 0.5 are regarded as “unexpected survivors” and those who die with a Ps of more than 0.5 as “unexpected deaths”. It must be emphasised that the term “unexpected death” does not necessarily equate with mis-treatment / medical negligence (so, for example, ten out of 100 patients with a probability of survival of 90% would be expected to die, although each individual death would be regarded as

“unexpected”). The probability of survival can, however, act as a useful guide as to the overall severity of a particular patient’s injuries. A further example calculation is given in chapter 8.2.

Comparing cohorts of patients

By means of further complicated mathematics, a comparison of the actual outcome with predicted outcome for a large number of patients treated within a certain hospital allows a conclusion to be reached as to whether the overall treatment provided for trauma patients by that hospital is statistically better, worse or no different from the national average (obtained from the national database comprising thousands of patients). This conclusion is presented in what is known as a “W” statistic (Yates et al., 1992; STAG, 1995). The “W” statistic is expressed as the number of “excess survivors” per 100 patients with major trauma, compared with what would be expected from the national database. Depending on the size of the database of the hospital being studied, the difference between the “W” statistic and what would be expected may be statistically significant. This is most easily portrayed in graphical form where confidence intervals can be added to each hospital’s “W” statistic. An example is shown in figure 2.7(i). In this figure, it can be seen that hospital B has performed statistically significantly better than both the UK norm and hospital A, which itself is performing significantly worse than the UK norm.

Figure 2.7(i) - “W” statistics and confidence intervals for two hospitals



Applications in medical and forensic practice

The AIS scoring system may usefully assist clinicians and pathologists to document injuries in a standardised way and help to cultivate a discipline of accurately describing and recording wounds. It may be applied both to patients who survive and to those who die following injury. For it to be useful, both the clinical and pathological information on which it is based needs to be detailed and accurate. In the context of death after trauma, it is particularly important that a detailed autopsy is performed in order not to underestimate the severity of the injuries and thereby under-score them (Harviel et al., 1989).

The RTS is used as a triage tool by those working in the front line in A&E medicine to identify critically injured patients (Gilpin & Nelson, 1991). This allows senior experienced doctors to be called at an early stage of resuscitation of an injured person when there is objective evidence of significant physiological derangement.

Analysis of injuries according to ISS is useful for research purposes. It enables the researcher to obtain a complete epidemiological picture when autopsy data are combined with prospectively collected hospital data - this situation in south-east Scotland has enabled many meaningful studies (Wyatt et al., 1995; Wyatt et al., 1996; Wyatt et al., 1997a; Wyatt et al., 1997b; Webb et al., 1999).

It has been proposed that the correlation of ISS with mortality may help to identify those patients who die unexpectedly after trauma (Friedman et al., 1996). However, this use of ISS, whereby cases of patients who died with low ISS are reviewed is limited to a certain extent, by a lack of physiological data. Despite the

fact that the mathematics may appear a little daunting, the use of TRISS methodology yields much more valuable information. This may be of benefit in comparing different systems of trauma care between different hospitals. When a problem with a particular unit, hospital or group of hospitals has been identified, it may be investigated and remedied, thereby closing the “audit loop”.

TRISS methodology may be used to yield individual probabilities of survival for patients treated in hospital. This allows attention to be focused on an examination of the care provided to patients with “unexpected deaths”. A review process of unexpected hospital deaths is critical to the improvement of hospital care. To be effective, peer review of these cases needs to involve clinicians from a variety of disciplines and who have no direct input into the management of that specific patient.

Medical practitioners are often asked (by the police, relatives, the media and most importantly, legal authorities and agents) to classify the severity of a particular injury or set of injuries. Often, the answer provided is rather subjective - however, the AIS provides an excellent objective way of classifying any individual injury as being “minor”, “moderate”, “serious”, “severe”, “critical” or “fatal”. This may assist in an explanation of the seriousness of a certain injury, particularly in relation to cases of assault. The medical expert witness may use the AIS, ISS and TRISS methodology as an aid when providing opinions on the severity and survivability of injuries sustained by particular individuals. This information is available from many hospitals in the UK, USA, Canada and numerous other countries which

prospectively collect relevant data (Champion et al., 1990a; Guirguis et al., 1990; Karmy-Jones et al., 1992; Yates et al., 1992; STAG, 1995).

The AIS and its derived ISS have further potential uses in forensic practice. In particular, they may be useful in the aftermath of mass disasters, as a means of classifying the injuries sustained. This would facilitate subsequent analysis of injury patterns.

Future trauma scoring systems

The AIS, combined with its derived ISS and TRISS methodology, have for many years combined together to be the pre-eminent scoring system used to assess the severity of trauma (and the likelihood of survival or death). Although the AIS / ISS system continues to occupy this position and is held by many to be superior to methods using other systems, such as that based upon the International Classification of Diseases (United States Department of Health and Human Services, 1997; Rutledge et al., 1998; Sacco et al., 1999), it has been criticised on several grounds. These include arguments that data collection is time-consuming and expensive (Osler et al., 1996), that pre-existing concomitant disease is ignored, particularly in the elderly (Pickering et al., 1999), that severe head injuries tend to be relatively underscored compared with injuries to other body regions (Gennarelli et al., 1994; McMahon et al., 1999) and that the system does not take into account bilateral injuries, or other injuries within the same body region (Baker et al., 1974). So, for

example (table 2.7D), a patient would score the same ISS whether he/she had a single femoral shaft fracture (AIS code 851814.3, AIS score = 3), bilateral femoral shaft fractures (AIS code 851814.3, AIS score = 3) or bilateral femoral shaft fractures (AIS code 851814.3, AIS score = 3) with an associated compound tibial shaft fracture (AIS code 853422.3, AIS score = 3) (Baker et al., 1974; AAAM, 1990).

In order to address some of these apparent deficiencies, several solutions have been proposed including "International Classification of Diseases Injury Severity Score" (ICISS), "New Injury Severity Score" (NISS), "Anatomic Profile" and its derived "A Severity Characterization of Trauma" (ASCOT) (Hoyt, 1998). The Anatomic Profile and its derived ASCOT allows for the number, severity and location of all injuries (Champion et al., 1990b; Copes et al., 1990), and the more recently described New Injury Severity Score (NISS) scores the patient's injuries according to the three most severe injuries, whether or not they are within the same body region (Osler et al., 1997). There is a certain amount of evidence to support the idea that NISS should replace ISS (Brenneman et al., 1998). However, none of the proposed modifications or proposed new scoring systems are as well established as TRISS methodology, which therefore seems to be likely to maintain its pre-eminent position, at least for the foreseeable future.

Table 2.7D - Examples of ways of achieving AIS = 3

Injury	AIS code	AIS score
Single femoral shaft fracture	851814.3	3
Bilateral femoral shaft fractures	851814.3	
	851814.3	3
Compound tibial shaft fracture	853422.3	3

2.8 The forensic autopsy and toxicological analyses

All deaths following trauma in south-east Scotland are referred to the Forensic Medicine Unit in the University of Edinburgh for autopsy on the instructions of the Procurator Fiscal. Autopsies are performed by consultant pathologists with a specific interest and training in Forensic Medicine. In cases of homicide or where there is any suspicion of foul play or other unusual circumstances (e.g. deaths at the workplace, where there may subsequently be a Fatal Accident Inquiry - see chapter 2.2), the autopsy is performed by two pathologists; in other cases, one pathologist is used.

Autopsies after trauma follow a standard procedure and are performed in a detailed fashion, in which even minor injuries are searched for and recorded in meticulous fashion. This procedure takes account of the needs of scoring according to the AIS, 1990 revision (AAAM, 1990; Wyatt et al., 1999b). During autopsies, routine blood and urine samples are taken and sent for toxicological analysis to the regional Forensic Science Laboratory. This analysis invariably includes assays for ethyl alcohol (ethanol), and in fatal fire deaths also for carboxyhaemoglobin saturation: in relevant cases, a full, qualitative and quantitative drug screen is also performed.

Each internal examination is preceded by a detailed external examination of the whole body, including the limbs, which are carefully palpated for fractures. The internal dissection part of the trauma autopsy is usually limited to the torso and main

body cavities (including the cranium), but includes, where relevant, careful (time-consuming) dissection of the spinal column. In certain cases, tissue is removed for fixation in formalin, in order to allow histological examination. Examples of conditions where histopathological examination is useful include diffuse axonal injury and fat embolism.

Autopsies remain the gold standard as far as ascertaining the exact nature and extent of all injuries after death are concerned. They have been recognised for some years as being a crucial part of TRISS methodology (Harviel et al., 1989), but the rates of autopsy vary considerably in different parts of the world (Pollock et al., 1993). The advantages for the studies within this thesis of having an autopsy rate for deaths after trauma approaching 100% should not be under-estimated.

2.9 Summary of data analyses in this study

Data sources for this study have been outlined above and include:

- police reports
- ambulance reports
- hospital case notes
- autopsy reports
- toxicological analyses

For the purposes of this study, analysis and scoring of the injuries which were described within the hospital notes and autopsy reports according to the Abbreviated Injury Scale, 1990 revision, was performed by a single trained individual within STAG (AAAM, 1990). A second individual was used to randomly check ISS for quality assurance. Mathematical analyses used to generate Ps according to TRISS methodology and to produce “W” statistics for certain populations were undertaken with the help of the statistician within STAG (see chapter 2.7 - Wyatt et al., 1998a).

Chapter 3 - Timing of trauma deaths

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3.1 Deaths amongst adults in south-east Scotland

Background

Trauma is the leading cause of death amongst young adults (Committee on Trauma Research, 1985; Anderson et al., 1988; Department of Health, 1992). Recognition of this, together with evidence of long-standing major shortcomings in trauma care in both the UK and the USA (Dove et al., 1980; McLaren et al., 1983; Anderson et al., 1988; Royal College of Surgeons of England, 1998; Yates et al., 1992; Esposito et al., 1995; Gorman et al., 1996) has resulted in increased interest in trauma and its management.

Data regarding the rate, causes and timing of deaths from trauma in the USA has been reported. All trauma deaths in those aged over 12 years in San Francisco in the two years 1977-1978 were described (Baker et al., 1980). Surprisingly, prior to the work contained within this thesis, no similar complete data exists for UK trauma deaths. An examination of the rate, causes and timing of deaths after trauma is of central importance in order to allow rational planning of both trauma care and trauma prevention in this country. This study describes the trauma deaths in the Lothian and Borders regions of south-east Scotland during a two year period, with emphasis on the time and place of death and potential for intervention.

Methods

Data was collected prospectively on all deaths from trauma in a two year period (1st February 1992 - 31st January 1994) for patients aged over 12 years in the Lothian and Borders regions of south-east Scotland. Data sources included: forensic medicine, police, ambulance, hospital and STAG records (as outlined in chapter 2). The same definition of trauma as that used previously by Trunkey was employed, allowing direct comparison with data from the USA. The AIS was used to derive ISS on all patients (chapter 2.7).

Results

During the two year period, there were 331 deaths following trauma in the study area. The population studied was slightly in excess of 0.8 million (Office of population censuses and surveys, 1993), giving an annual rate of death from trauma was 20 per 100,000. Forty-nine percent of those who died were aged less than 40 years. The age and sex distribution of the patients are shown in figure 3.1(i).

The vast majority of deaths following trauma resulted from blunt injury (309 deaths (93%). Of the 22 penetrating injuries, nine involved firearms (one homicide, eight suicides) and 13 involved knives (including 11 homicides). Amongst the 331 deaths, there were 26 homicides (8%) and 98 suicides (30%). The remaining 207 deaths (62%) are believed to have been unintentional (“accidental”).

Table 3.1A demonstrates that road accidents were the leading cause of death. These comprised two main groups: young car occupants and older pedestrians. Fifty-two deaths were caused by falls, with 35 patients (67%) falling more than two metres. Twelve deaths (4%) occurred at the workplace: these included seven crush injuries.

Two hundred and ninety-eight deaths (90%) occurred within 24 hours of injury. The temporal distribution of these deaths is shown in figure 3.1(ii). Two hundred and forty-eight patients died instantaneously and had injuries acknowledged to be unsurvivable (AIS 6, ISS = 75), or were dead when first found. A further five patients died within an hour of injury. All of these patients died before reaching hospital, either at the scene or in transit. The age, sex and injuries of each of these five patients is shown in table 3.1B. None appeared to have died from airway obstruction which would have been amenable to first aid measures from bystanders with no equipment.

Seventy-eight patients showed signs of life at some stage and received treatment from the emergency and subsequently hospital services. Figure 3.1(iii) shows that 19 patients (7%) died between one and four hours following trauma, 59 patients (17%) died after more than four hours (Wyatt et al, 1995).

83 patients had injuries which were "not scorable" - these included those patients found dead after hangings or drownings. The remaining 248 patients had injuries which were scored to produce an ISS. These ISS are demonstrated in figure 3.1(iv), according to the timing of death.

During the study period, 2150 patients treated for trauma in south-east Scotland were entered into the STAG database. This data has been independently analysed and validated by the MTOS (UK) and indicates that this centre performed statistically significantly better than the UK norm, with 1.86 “excess” survivors per 100 patients (W statistic 1.86, Z statistic 4.83) (MTOS UK personal communication, 1994).

Figure 3.1(i) Age and sex distribution of trauma deaths in south-east Scotland

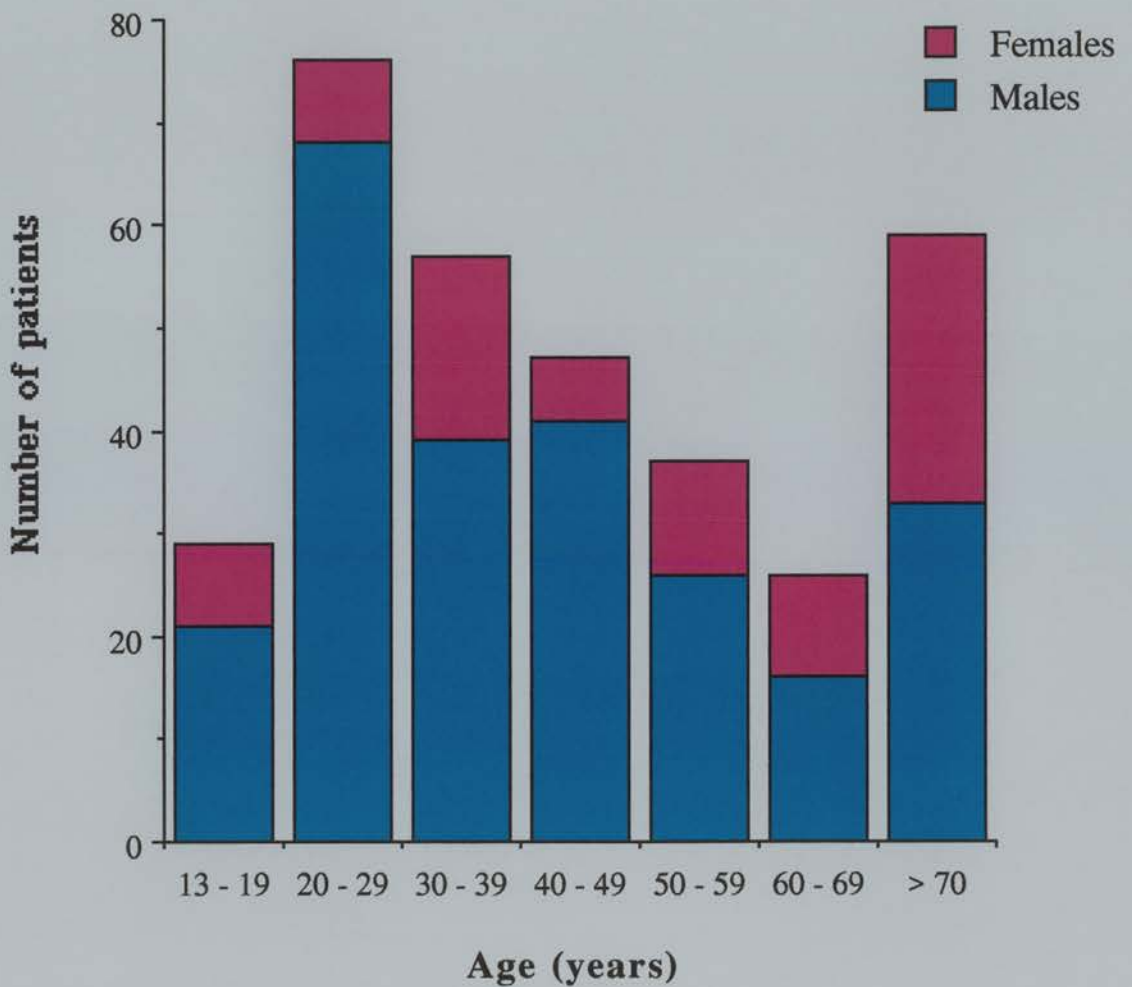


Table 3.1A - Aetiology of trauma deaths in south-east Scotland

Mechanism	Homicide	Suicide	Accident	Total (%)
Road traffic collision	0	3	121	124 (37%)
Fall	1	16	35	52 (16%)
Hanging	0	51	0	51 (15%)
Drowning	0	11	12	23 (7%)
Assault	21	0	0	21 (6%)
Burns / smoke inhalation	0	1	19	20 (6%)
Hit by train	0	3	5	8 (2%)
Electrocution	0	3	2	5 (2%)
Suffocation	2	1	2	5 (2%)
Other	0	11	11	22 (7%)
TOTAL	26	98	207	331

Figure 3.1(ii) - Distribution of deaths in the first 24 hours

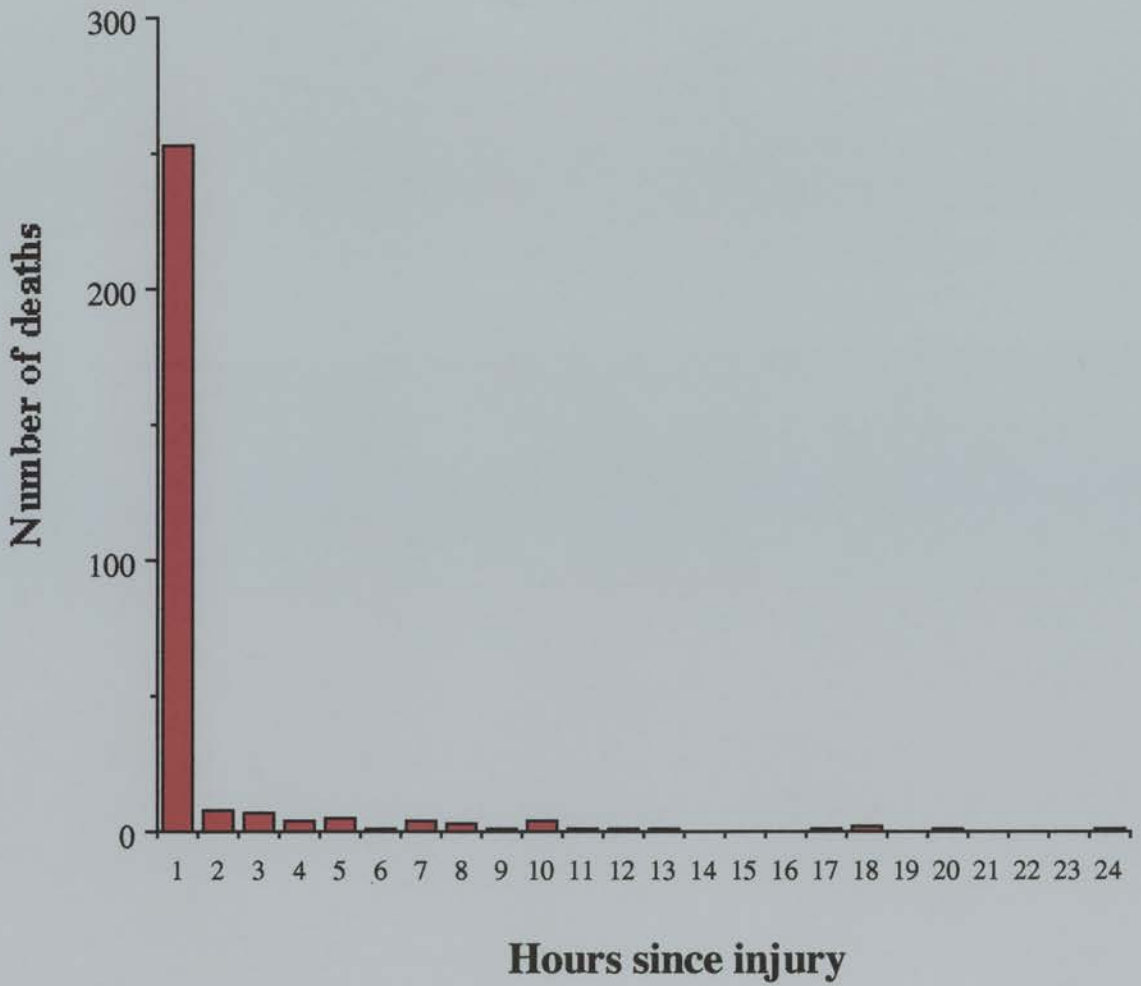


Table 3.1B - The five non-instantaneous pre-hospital deaths

No.	Age	Sex	Mechanism	Time to death	ISS
1	27 yrs	M	drowning	42 mins	not scorable
2	18 yrs	M	car driver	35 mins	34
3	23 yrs	M	car passenger	45 mins	33
4	43 yrs	M	pedestrian	35 mins	34
5	19 yrs	M	car driver	61 mins	16

Figure 3.1(iii) - Temporal distribution of trauma deaths in south-east Scotland

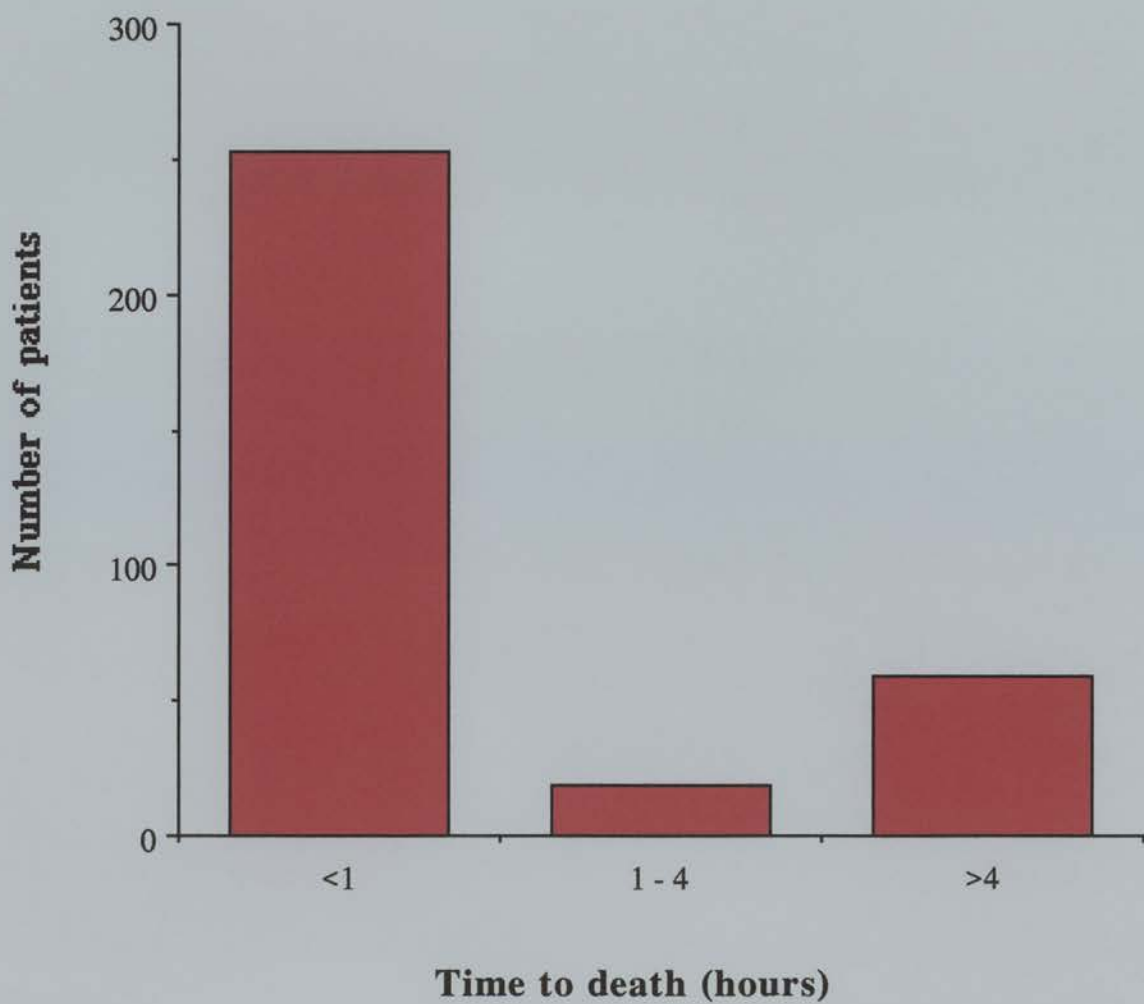
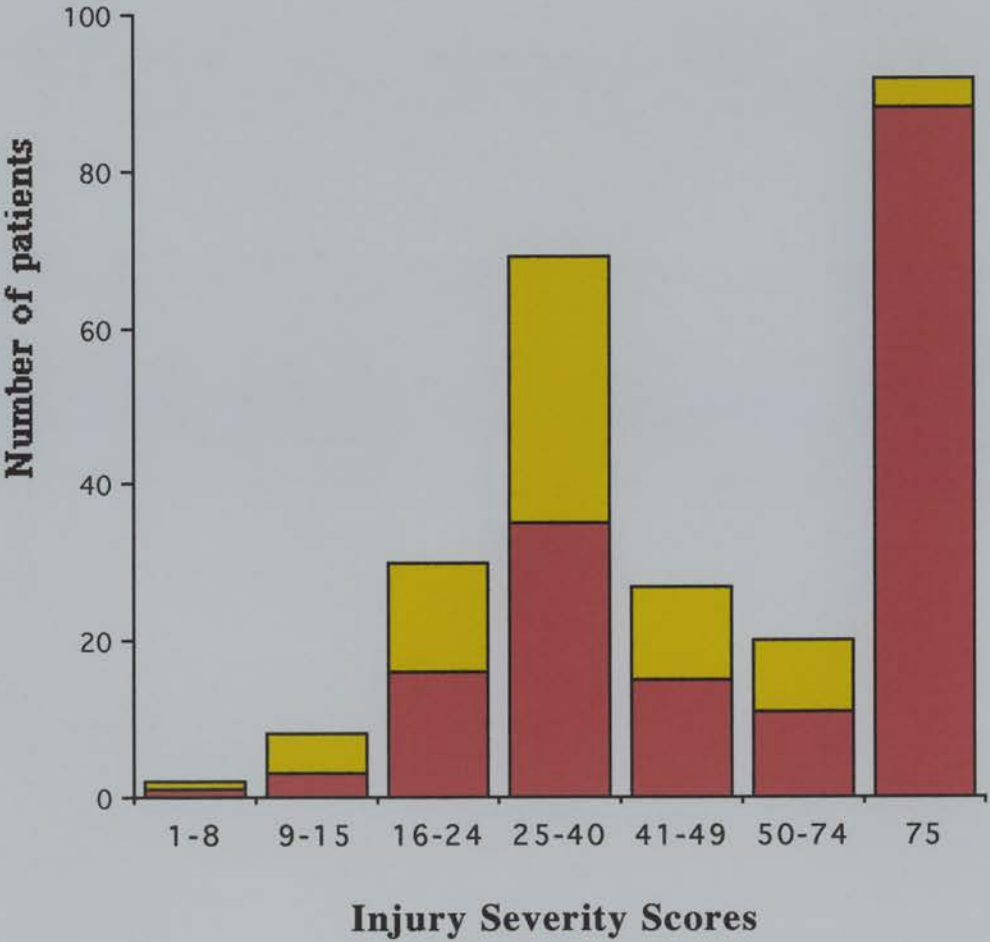


Figure 3.1(iv) - ISS of scorable deaths in south-east Scotland



Discussion

Death and injury following trauma are emotive subjects. Considerable debate has taken place amongst doctors, the general public and politicians as to what constitute the best mechanisms to deliver appropriate levels of care (West et al., 1988; O'Kelly & Westaby, 1990; Laurence, 1993; Nicholl et al., 1993; Redmond, 1993; Scottish Office Home and Health Department, 1994; Nicholl et al., 1995a; Nicholl & Turner, 1997). Some trauma statistics, such as death and injury following road traffic collisions, are carefully and reliably collated in this country (Department of Transport, 1996). There is, however, a surprising paucity of information on the global aspects of trauma and particularly, on the timing of death and the potential for successful medical intervention.

This study is the first in the UK to incorporate the contributions made by both in-hospital and out-of-hospital deaths, where post mortem information is available for every death. This has been facilitated by the unique method of data collection in Scotland where law officers in the Crown Office work closely with the medical staff in the Forensic Medicine Unit (see chapter 2).

The results of this study confirm that trauma plays a significant part in premature death in the UK, especially amongst young males. Road traffic collisions account for the greatest number of these. This is in keeping with previous data from this country, other parts of Europe and the USA (Committee on trauma research, 1985; Daly & Thomas, 1992; Department of Health, 1992; Department of Transport, 1996; Eachempati et al., 1998). The 1993 financial costs associated with

road traffic collisions have been estimated at £744,000 per death and £84,000 for individuals sustaining serious injury (Department of Transport, 1994). The overall annual cost to the exchequer from such deaths in the UK is therefore enormous.

Although road traffic collisions also account for a considerable number of deaths in the USA, there were marked differences in the patterns of death following trauma. Cultural and geographical differences may be partly responsible for this. For example, deaths from drowning in the USA are not only seen in marine and fresh water environments, but also in the context of increased accessibility to home swimming pools (O'Carroll et al., 1988). By contrast, despite a coastline in this study of 160 kilometres, there were only 23 deaths from drowning and none occurred in a home swimming pool, findings in keeping with a larger study in south-east Scotland (chapter 4.4, Wyatt et al., 1999c).

The USA experience a far greater proportion of penetrating trauma (Committee on trauma research, 1985; Centers for Disease Control, 1994; Eachempati et al., 1998). This is demonstrated by deaths from violence, which show marked differences in both aetiology and incidence (Committee on trauma research, 1985; Eachempati et al., 1998). The total number of homicides in south-east Scotland in the two years of this study for a population of 0.8 million is similar to that seen in a single day amongst the same sized population in many American cities (Fingerhut et al., 1992)! In keeping with previous data from other parts of the UK, the majority of homicides in this study resulted from blunt injury or penetrating injury caused by knives, rather than the firearms commonly used in the USA (Committee on trauma

research, 1985; Daly & Thomas, 1992; Centers for Disease Control, 1994; Gorman et al., 1995). There was only one homicide involving firearms, although eight individuals used guns to commit suicide, possibly reflecting the ready access to this mode of death within rural or farming communities.

Following publication of data concerning the timing of trauma deaths in San Francisco, the concept of a trimodal distribution of such deaths has become accepted (Baker et al., 1980; Trunkey, 1983). The first peak of deaths (50%) occurs soon after trauma and represents overwhelming injury. The second peak of deaths (30%), includes those patients who die up to four hours after trauma, the third peak (20%) those who die after four hours. It is believed by some that there is great potential to reduce deaths from trauma by improving treatment to diminish the second and third peaks (Royal College of Surgeons of England, 1988; British Association Board of Science and Education, 1993; Committee on Trauma of the American College of Surgeons, 1997). This belief has moulded trauma care services in both the USA and the UK, with development of paramedic services and trauma centres (Royal College of Surgeons of England, 1988; O'Kelly & Westaby, 1990; Redmond, 1993; Scottish Office Home and Health Department, 1994).

This study demonstrates that a trimodal distribution of trauma deaths does not exist in south-east Scotland. These results have significant implications for the provision of trauma services. It may be tempting to attribute the lack of demonstrable second and third peaks of trauma deaths in south-east Scotland to high quality treatment. There is certainly evidence to support this view, but it seems

much more likely that the results reflect the previously mentioned differences in patterns of trauma seen in the UK when compared with the USA. This issue is addressed in chapter 3.3 by an analysis of the temporal distribution of trauma deaths during 1995 in the whole of Scotland.

The role of basic life-saving techniques by members of the lay public in order to save a significant number of pre-hospital deaths from trauma has been proposed (Hussain & Redmond, 1994). Although this may be an appealing viewpoint, in that it provides clear direction as to how deaths may be prevented, the results of this study confirm previous scepticism and provide no evidence to support this view (see chapter 8).

The temporal distribution of trauma deaths in this study indicates that the potential for “saving lives” from trauma in south-east Scotland by improving treatment is significantly less than that suggested by previous work (Anderson et al., 1988; Royal College of Surgeons of England, 1988). Heightened awareness already exists for the need for victims of major trauma to be treated promptly and efficiently by properly trained, experienced personnel (Driscoll & Vincent, 1992; Hoff et al., 1997). This necessitates rapid delivery and concentration of major trauma patients to centres which can provide senior experienced personnel of the relevant disciplines, together with the appropriate diagnostic and therapeutic facilities on a 24 hour basis (Scottish Office Home and Health Department, 1994).

3.2 Deaths amongst children after trauma in south-east Scotland

Background

Trauma is the leading cause of death amongst children aged over one year in the UK (Child Accident Prevention Trust, 1989; Department of Health, 1992). This problem has been identified as being worthy of special attention by the Government. The “Health of the Nation” document sets a target of reducing the death rate for “accidents” in children by at least 33% by the year 2005, to no more than 4.5 per 100,000 (Department of Health, 1992). The principal methods of reducing the death rate are either to improve treatment for those injured or prevent injuries occurring in the first place. An examination of the timing of death after injury provides insight into the potential of each stratagem.

Methods

Deaths following trauma amongst children aged less than 15 years in Lothian and Borders regions of south-east Scotland during the 11 years 1985 - 1995 were identified from Forensic Medicine and Procurator Fiscal records (see chapter 2). A cross check was performed against data from the Registrar for Deaths in order to confirm that the dataset was complete. The mechanism of injury, times of trauma and

death were obtained from the above sources and using police, ambulance and hospital records (see chapter 2). ISS were calculated for each child, using the AIS, 1990 revision (AAAM, 1990).

Results

One hundred and thirty-eight children (84 boys, 54 girls) died following injury during the 11 years. The population of children aged less than 15 years for the region in the 1991 Census was 146,826, hence the overall death rate was 8.5 per 100,000 children per year (Office of Population Censuses and Surveys, 1993). The rate varied from year to year (4.1 deaths per 100,000 in 1992 to 18.4 per 100,000 in 1991), with no discernible trend (table 3.2A).

Fifty-seven deaths occurred amongst pre-school children (aged less than five years). Ninety-nine children (72%) died within one hour of injury, or were dead when found (figure 3.2(i)). Ninety-two of these children showed no signs of life when the ambulance crew arrived at the scene. These included 40 children who had injuries considered to be unsurvivable (ISS = 75) and 36 other children who were found dead after an unwitnessed incident. The time of death according to mechanism of injury is shown in table 3.2B.

Information collected allowed specific “causes” of incidents resulting in 81 fatalities to be identified (table 3.2C). Twenty pre-school children died having been

left unsupervised in the presence of an obvious danger (access to matches, deep water, an open road or an unguarded drop).

Table 3.2A - Annual rates of paediatric trauma deaths

Year	Number of deaths	Death rate (Number per 100,000 children per year)
1985	14	9.5
1986	13	8.9
1987	9	6.1
1988	16	10.9
1989	11	7.5
1990	7	4.8
1991	27	18.4
1992	6	4.1
1993	11	7.5
1994	12	8.2
1995	12	8.2
Overall 1985 - 1995	138	8.5

**Figure 3.2(i) - Time of paediatric trauma death
in south-east Scotland**

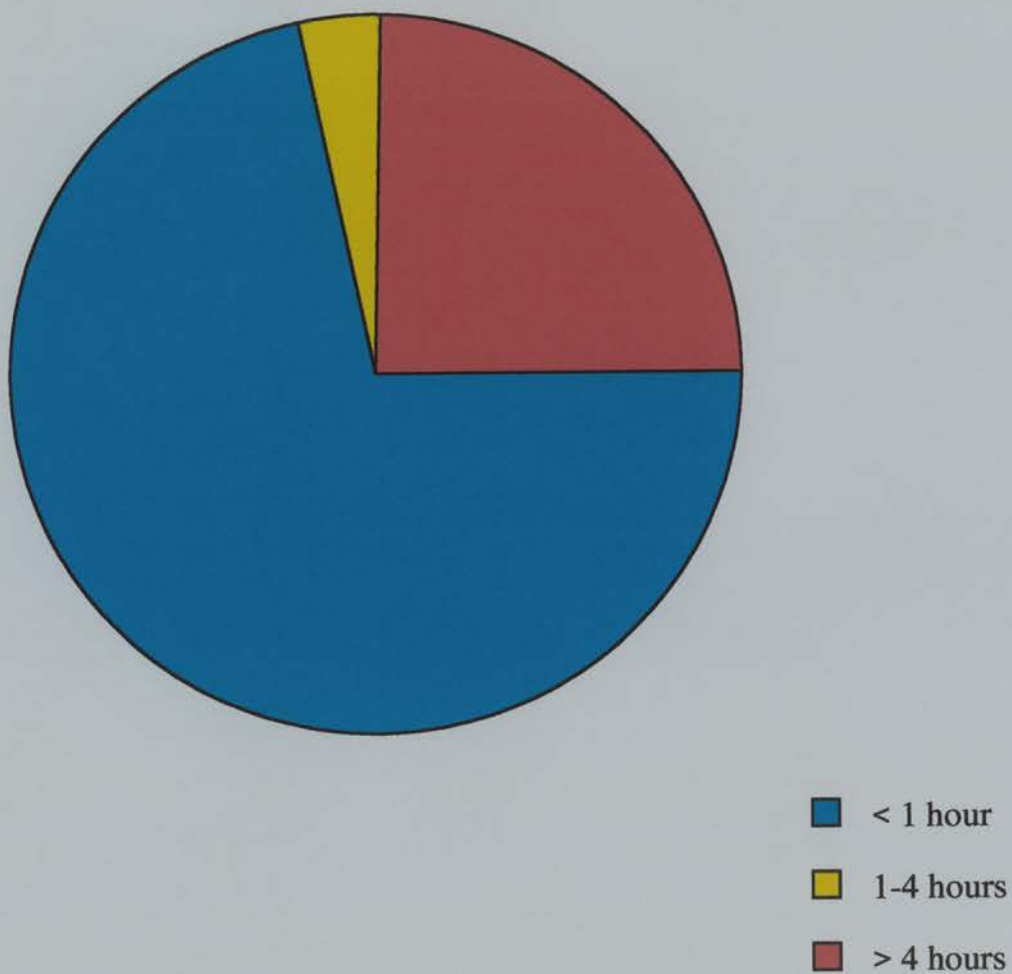


Table 3.2B - Mechanism, age and time of death after injury

Mechanism of injury	Mean age (yrs)	Time of death after injury			Number of deaths
		< 1 h	1 - 4 h	> 4 h	
RTC (pedestrian)	8.6	16	0	16	32
RTC (car passenger)	5.5	22	2	2	26
RTC (pedal cyclist)	11.7	6	0	3	9
Fall from a height	4.8	6	1	4	11
Hanging	11.5	10	0	1	11
Drowning	5.4	13	0	2	15
Fire	4.5	20	1	1	22
Other	3.6	6	1	5	12
TOTAL	6.7	99	5	34	138

RTC = Road Traffic Collision

Table 3.2C - Potentially preventable factors involved in paediatric trauma deaths in south-east Scotland

Major factor implicated	Number of children's deaths resulting
Poor or no supervision of children <5 years	20
Adult vehicle driver error	26
Children playing in the road	3
Child trying to cross motorway / dual carriageway	4
Defective cycle brakes	2
No bicycle lights	1
Deep pothole in road causing cyclist to fall	1
Unguarded coal or unsafe electric fire	4
Drunk parent causing fire	3
Petrol / matches easily available for child's use	2
House windows too small to escape from fire	2
Unattended chip pan	1
Unattended public swimming pool	1
Unsafe / illegal farming equipment	2
Collapsing unsafe masonry	1
Poorly designed cot	1
Asphyxia from telephone cord	1
Access to derelict quarry or mill	2
Riding a horse without a saddle or helmet	1
Deaths related to illegal drug use	3

Discussion

Children continue to die as a result of injury with relatively predictable causes (Department of Health, 1999). In the relatively small size of the region under consideration, the death rate following trauma among children in south-east Scotland fluctuates somewhat from year to year, but the overall rate remains unacceptably high. In order to achieve the Government target for 2005, this death rate needs to be reduced by 47%. The vast majority of children in this study were either dead when found or died at the scene of the injury before receiving medical attention, implying that the greatest potential to reduce the death rate lies with injury prevention measures, rather than with improved treatment. This argument to focus upon injury prevention is even stronger, considering that a child who is prevented from sustaining an injury will be able to subsequently enjoy a "normal" life, whereas a child with severe injury whose life is "saved" by improved treatment is likely to suffer from long-term disability (Hu et al., 1994).

Timing of death varied considerably according to mechanism of injury. As a result, the hospital practitioner treating children following major trauma may well be ignorant of the fact that drownings, fires and hangings are responsible for a such a high proportion of deaths in children. Certainly, for these mechanisms of injury, improved hospital treatment appears to offer no hope of significantly reducing the paediatric trauma death rate. Those children who do survive to hospital, only to die later are principally those who have been involved in road traffic collisions or sustained falls. Attempts to improve hospital treatment need to focus upon these

children. Previous research indicates that there may be some (albeit limited) potential to prevent certain in-hospital deaths amongst children who have sustained head injury by improving treatment (Sharples et al., 1990). Problems include both delay in recognising the need for transfer to a neurosurgical centre and then difficulty in accomplishing the transfer in a timely yet safe fashion (Gentleman & Jennett, 1990; O'Sullivan et al, 1990). Since children present relatively infrequently with major injuries to hospital in Scotland, arguments for centralisation of paediatric trauma services in order to concentrate expertise, thereby reducing the death rate, remain controversial (Johnston et al., 1996).

The potential (if any) for improvement in survival by providing seriously injured children with earlier medical attention at the scene is very difficult to quantify, but appears to be limited, considering the fact that the majority of children either had unsurvivable injuries or were found dead after an unwitnessed incident. These results are in keeping with those relating to adults (Wyatt et al., 1995).

It is clear that, as with adult trauma deaths, the greatest potential to reduce the number of paediatric trauma deaths lies with introducing and implementing effective injury prevention measures. The high proportion of deaths related to road traffic collisions confirms data from elsewhere (Keeling et al., 1985) and demonstrates the need to concentrate efforts in this area (see chapter 5.2). Research designed to identify appropriate injury prevention measures should be strongly encouraged and supported. The aim of significantly reducing the number of deaths

from injury amongst children will not be achieved unless this is borne in mind and resources allocated appropriately.

3.3 Timing of deaths after trauma in other parts of

Scotland

Introduction

The oft-quoted trimodal distribution of trauma deaths in the USA was initially described in 1980, based upon data which was collected from San Francisco in 1977 (Baker et al., 1980; Trunkey, 1983). In chapter 3.1 and 3.2 it has been shown that the distribution of deaths following trauma amongst both adults and children in south-east Scotland does not follow this classical trimodal pattern. Instead, the vast majority of those who died after trauma in south-east Scotland, did so within an hour of trauma and without ever reaching hospital alive (Wyatt et al., 1995; Wyatt et al., 1997a). In order to try to determine if this is simply a reflection of a phenomenon local to south-east Scotland, or whether it reflects a more widespread situation, the timing of deaths following trauma throughout Scotland was studied during the year of 1995.

In addition to examining the temporal pattern of deaths following trauma, this study also aimed to determine if there were significant differences in the pattern of trauma between the various regions in Scotland. Major differences between regions in terms of the mechanisms of injury responsible for death might be largely responsible for differences in the timing of death. Similarly, inter-regional variations, if present, would have implications as far as the way in which it would be most appropriate to

target injury prevention measures, and organise both prehospital care and emergency hospital services in each region.

Methods

Data was collected prospectively on all deaths from trauma in Scotland during the 12 months comprising 1995. Data sources included: forensic medicine, police, ambulance, hospital and STAG records (as outlined in chapter 2). In addition, data from the Registrar General was used in order to check that the dataset was complete (see chapter 2.4). The same definition of trauma as that used previously by Trunkey was employed, allowing direct comparison with data from the USA. Details of all injuries sustained were extracted and scored according to the AIS in order to derive ISS on all patients (chapter 2.7).

For the purposes of this analysis, and to allow comparisons between different parts of Scotland, the country has been divided into four regions, centred upon each of the four large cities where the majority of the population are based (Edinburgh, Glasgow, Dundee, Aberdeen).

For the purposes of this study, these four regions comprised:

- South-east (Lothian and Borders regions, including Edinburgh and Livingston)
- South-west (Strathclyde, Dumfries and Galloway, including Glasgow, Paisley, Kilmarnock and Airdrie)
- Central and East (Fife, Tayside and Central regions, including Dundee, Perth, Stirling, Dunfermline, Kirkcaldy)
- North and Highlands (Grampian and Highland regions, Orkney, Shetland and Western islands, including Aberdeen, Inverness and Fort William)

Results

During 1995 in Scotland, there were 1305 deaths following trauma. Six hundred and thirty-nine (49.0%) of these deaths occurred in the “south-west” of Scotland. Overall, 959 (74%) of those who died were either found dead or died at the scene of the injury, 15 (1%) died in transit to hospital and 331 (25%) died having reached hospital alive. Individuals dying at the scene of injury accounted for the majority of deaths in all regions, with proportions varying from 69% in the south-west to 82% in the north (table 3.3A). Scoring according to the AIS revealed that a significant proportion of those who died had at least one unsurvivable injury (AIS = 6, ISS = 75 - table 3.3B). Overall, 268 out of the total 1305 deaths had at least one unsurvivable injury and a significant proportion of the remainder had sustained

fatal injuries which are not scorable according to the AIS (e.g. drowning, hanging, strangulation).

The type of trauma varied slightly between regions, although the vast majority of deaths followed blunt trauma in all regions (table 3.3C). Similarly, there were some differences in the mechanisms of injury causing death between regions, although road traffic collisions were the leading cause of death in all regions (table 3.3D).

**Table 3.3A - Place of death following trauma throughout Scotland
in 1995**

Place of death	South-east deaths (% in region)	South-west deaths (% in region)	Central deaths (% in region)	North deaths (% in region)	Overall deaths (% overall)
Scene	137 (72%)	440 (69%)	180 (79%)	202 (82%)	959 (74%)
Transit	2 (1%)	8 (1%)	3 (1%)	2 (1%)	15 (1%)
Hospital	52 (27%)	191 (30%)	45 (20%)	43 (17%)	331 (25%)
Total	191	639	228	247	1305

Table 3.3B - Unsurvivable injuries in Scotland in 1995 by region

Type of trauma	South-east deaths (% in region)	South-west deaths (% in region)	Central deaths (% in region)	North deaths (% in region)	Overall deaths (% overall)
Unsurvivable AIS 6; ISS 75	46 (24.1%)	120 (18.8%)	40 (17.5%)	62 (25.1%)	268 (20.5%)
Potentially survivable	145 (75.9%)	519 (81.2%)	188 (82.5%)	185 (74.9%)	1037 (79.5%)
Total	191	639	228	247	1305

Table 3.3C - Type of trauma causing death in Scotland in 1995

by region

Type of trauma	South-east deaths (% in region)	South-west deaths (% in region)	Central deaths (% in region)	North deaths (% in region)	Overall deaths (% overall)
Blunt	175 (91.6%)	585 (91.5%)	216 (94.7%)	234 (94.7%)	1210 (92.7%)
Penetrating	16 (8.4%)	54 (8.5%)	12 (5.3%)	13 (5.3%)	95 (7.3%)
Total	191	639	228	247	1305

**Table 3.3D - Mechanisms of injury causing death in regions of
Scotland in 1995**

Mechanism	South-east	South-west	East	North	Total
RTC	64	172	80	90	406
Fall	48	132	34	44	258
Hanging	33	99	44	31	207
Drowning	8	57	25	38	128
Fire	6	53	16	7	82
Other	32	126	29	37	224
Total	191	639	228	247	1305

Discussion

The principal finding of this study is that the great majority (75%) of all those who died following trauma in 1995 in Scotland were either found dead or died at the scene of the injury. The predominance of prehospital deaths (and in particular, deaths at scene) over hospital deaths as previously found amongst both adults and children in south-east Scotland (Wyatt et al., 1995; Wyatt et al., 1997a), clearly also exists in other parts of Scotland, with the proportion of those dying at scene ranging from 69% in south-west Scotland to 82% in north Scotland. The large number of deaths at scene received significant contributions from those individuals who had sustained injuries acknowledged to be unsurvivable (amounting to 20.5%) of the total. The relatively small number of individuals who died in transit to hospital (1% of the total) also confirms previous findings and tends to question the amount of potential which exists to directly “save lives” in the prehospital setting by improving prehospital care.

This study demonstrates that throughout Scotland in 1995, the vast majority of deaths after trauma (92.7%) followed blunt trauma. Clearly, as shown in table 3.3D, some variations do exist between regions in terms of the mechanisms of trauma responsible for trauma death. It is difficult to make meaningful comparisons of either total trauma death rates or death rates from specific forms of injury between populations within different regions because of the impact of individuals moving between regions. Perhaps the most extreme example of this is the death rate from avalanches and high falls on mountains amongst mountaineers - clearly, such deaths

can only occur in the presence of mountains, and most appear to involve individuals visiting from outside the region.

Having acknowledged regional differences in mechanisms of injury, neither this, nor any possible regional variations in the quality of trauma care, appear to significantly impact upon the timing of trauma deaths in Scotland. There is no evidence to support a trimodal distribution of trauma deaths in any region in Scotland.

3.4 Conclusions

The concept of a trimodal temporal distribution of trauma deaths was based upon data from the USA which is now more than 20 years old (Trunkey, 1983). The concept is still considered important amongst those who are responsible for the treatment of individuals presenting to hospital after injury (American College of Surgeons, 1997). The timing of death following trauma amongst both adults and children in south-east Scotland does not follow a trimodal distribution. Arguments that the timing of trauma deaths in Lothian and Borders regions of south-east Scotland might be significantly different because of either different mechanisms of injury and/or different quality of hospital care, clearly do not appear to apply.

The lack of a significant “second peak” of “early” deaths (as described by Trunkey) could be explained in different ways. Firstly, it is possible that a trimodal temporal distribution of trauma deaths did previously exist in Scotland, but that improved trauma care has reduced the number of hospital deaths, thereby diminishing the proportion of deaths seen in the “second” or “third” peaks. Secondly, the results may simply reflect the acknowledged very different type of trauma seen in Scotland, when compared with the USA - certainly, there is evidence to suggest that there is a different temporal distribution of trauma deaths in urban parts of the USA when compared with rural parts, perhaps reflecting different types of trauma which each experiences (Meislin et al., 1997). Whichever explanation most accurately reflects the truth, it is clear that there is currently more potential to reduce the trauma death rate

in Scotland through injury prevention measures, rather than through improved treatment.

Chapter 4 - Analysis of adult deaths according to mechanism of injury

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4.1 Introduction

The data presented in chapter 3 demonstrates that the general perception of trauma as comprising solely (unintentional) “accidents” is untrue, since significant proportions of trauma deaths in Scotland are the result of homicides and suicides. Similarly, rather than existing as an easily identifiable discrete entity, fatal trauma actually takes many shapes and forms (chapter 3). Analysis of various cohorts of individuals who have died as a result of trauma needs to take into account the different patterns of injuries and also whether or not the injuries were sustained unintentionally or intentionally. Conclusions regarding the cause, treatment and prevention of injuries from one mechanism of trauma clearly do not apply to another, hence the importance of analysis of injuries and deaths according to mechanism of injury. This chapter investigates deaths from trauma amongst adults in Scotland according to various mechanisms of injury.

4.2 Suicidal high falls

Background

The potential risk of serious injury and death resulting from a fall from a height has been recognised for thousands of years (Matthew, Holy Bible). In more modern times, studies have demonstrated that the risk of death following a high fall depends to a large extent upon the distance fallen, although other factors such as the age of the victim, the position of the body on landing and the surface landed upon can play a considerable part (de Haven, 1942; Snyder, 1963; Warner & Demling, 1986; Steedman, 1989; Risser et al., 1996). However, despite the relatively soft landing and associated slow deceleration by a landing into water, the experience gained from studying very high falls into water demonstrates that they are consistently associated with very serious injury (Lukas et al., 1981; Li & Smialek, 1994). For falls onto a firm surface, the correlation between height of fall and ISS is consistent enough to allow some researchers to suggest that the ISS may play a useful role in helping to estimate the height fallen (Steedman, 1989; Lau et al., 1998), although others contest this view (Goodacre et al., 1999).

Most studies of high falls describe unintentional (“accidental”) causes and highlight the potential to prevent such incidents in certain groups (e.g. unsupervised young children near open windows, college students falling from balconies, construction workers, roofers, window cleaners) (Copeland, 1989a; Mathis et al.,

1993; Muir & Kanwar, 1993; Rivara et al., 1993; Mosenthal et al., 1995). The use of a high fall as a means of committing suicide is also not new. In 1190, anti-Jewish riots were rife throughout England - as a result of one of these riots, dozens of Jews trapped in York Castle chose to jump from the top of Clifford's Tower to their deaths, rather than hand themselves over to the mob (Gillingham, 1978). Suicide is relatively common in the modern Western world - in the UK the government identified mental illness and associated suicide as one of the key areas worthy of attention in order to improve the nation's health (Department of Health, 1992; Secretary of State for Health, 1999). Certain methods of suicide, such as poisoning and hanging appear to be particularly frequent, but suicidal jumps appear to be less common (Pounder, 1993). This study investigates the epidemiology of suicidal falls in south-east Scotland.

Methods

Deaths following trauma in south-east Scotland were studied prospectively between 1992 and 1998 in a collaborative project involving the Forensic Medicine Unit of the University of Edinburgh, STAG and the A&E Department of the Royal Infirmary of Edinburgh. Amongst the traumatic deaths, all deaths following high falls between 1992 and 1998 were identified, and the peri-mortem circumstances studied, enabling suicidal deaths to be identified. Deaths following falls which were down

stairs or from a standing height only (i.e. less than two metres) were excluded from the analysis.

Results

Sixty-three individuals (50 males, 13 females) appeared to have committed suicide by falling or jumping from a height during the seven years of the study, which considering the known population of 830,000, reflects a rate of suicidal falls of 1.1 deaths per 100,000 per year (Office of population censuses and surveys, 1993). The age and gender of those who died is shown in figure 4.2(i). The sites where the high falls occurred is shown in figure 4.2(ii): the two most frequent sites for suicidal falls were two bridges, which accounted for 23 deaths (36.5% of the total). One of these bridges is 180 feet high, the other is 80 feet high.

The background to the suicides appeared to be diverse. Analysis of the evidence implicated certain factors as being important in precipitating the suicide. These factors are shown in table 4.2A. Psychiatric illness appeared to be an important factor, with 44 individuals (70%) having been treated for psychiatric symptoms. Eighteen of those who died had previously attempted suicide, but only 13 told someone else that they were feeling suicidal prior to the fatal fall. Only six individuals left a suicide note.

Fifty-four individuals died at the scene of the fall, with all but two of these being dead when found. The remaining nine individuals survived to reach hospital

alive, but died later of their injuries. Analysis of the injuries sustained revealed ISS ranging from 16 to 75 as shown in figure 4.2(iii). Eighteen of the 22 individuals with an ISS of 75 had injuries acknowledged to be unsurvivable (table 4.2B). Five individuals had more than one unsurvivable injury. Analysis of the pattern of injuries for each individual allowed the most severely injured body region to be identified according to the AIS. The body regions responsible for maximum AIS (MAIS) for each patient are shown in figure 4.2(iv).

Figure 4.2(i) - High fall suicides by age and sex

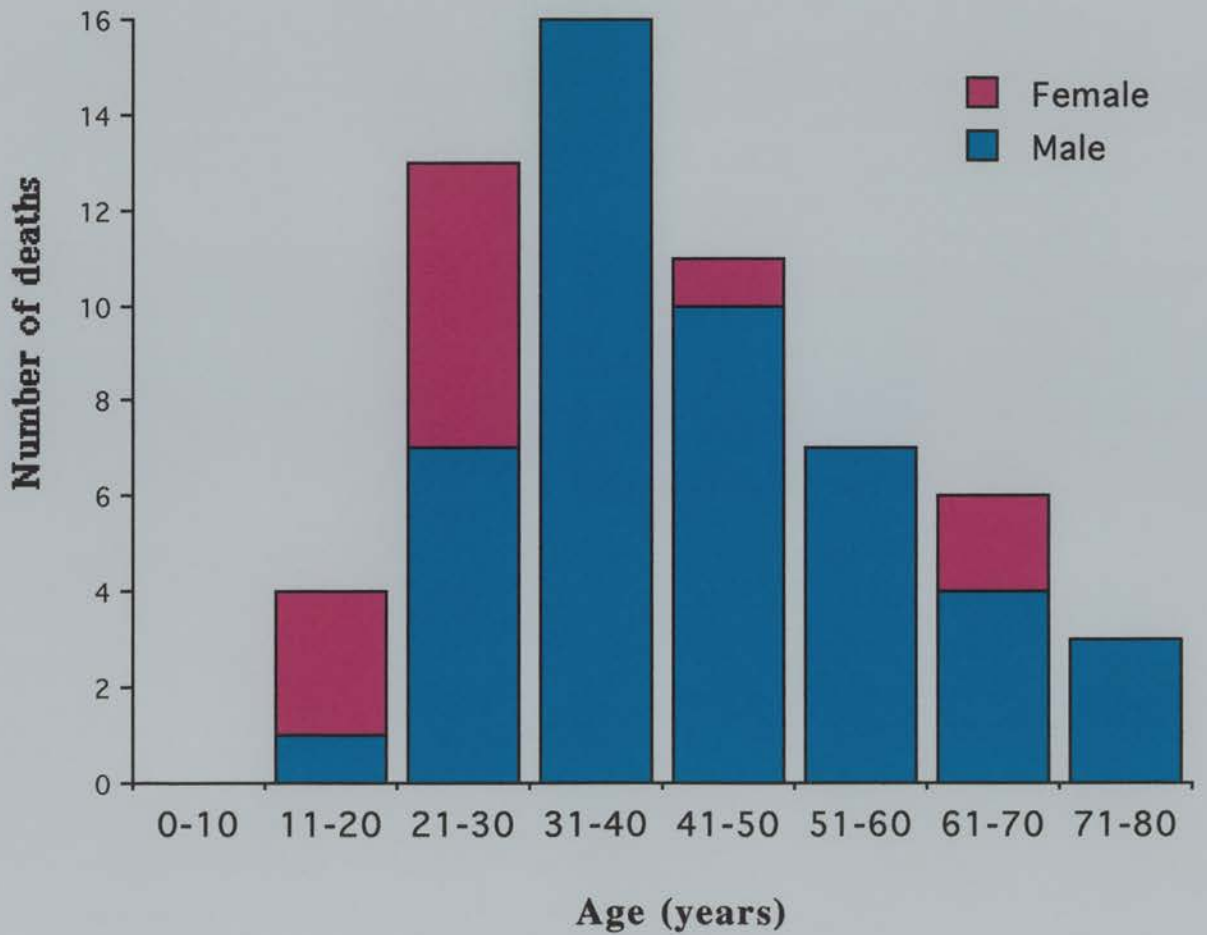


Figure 4.2(ii) - Site of suicidal falls

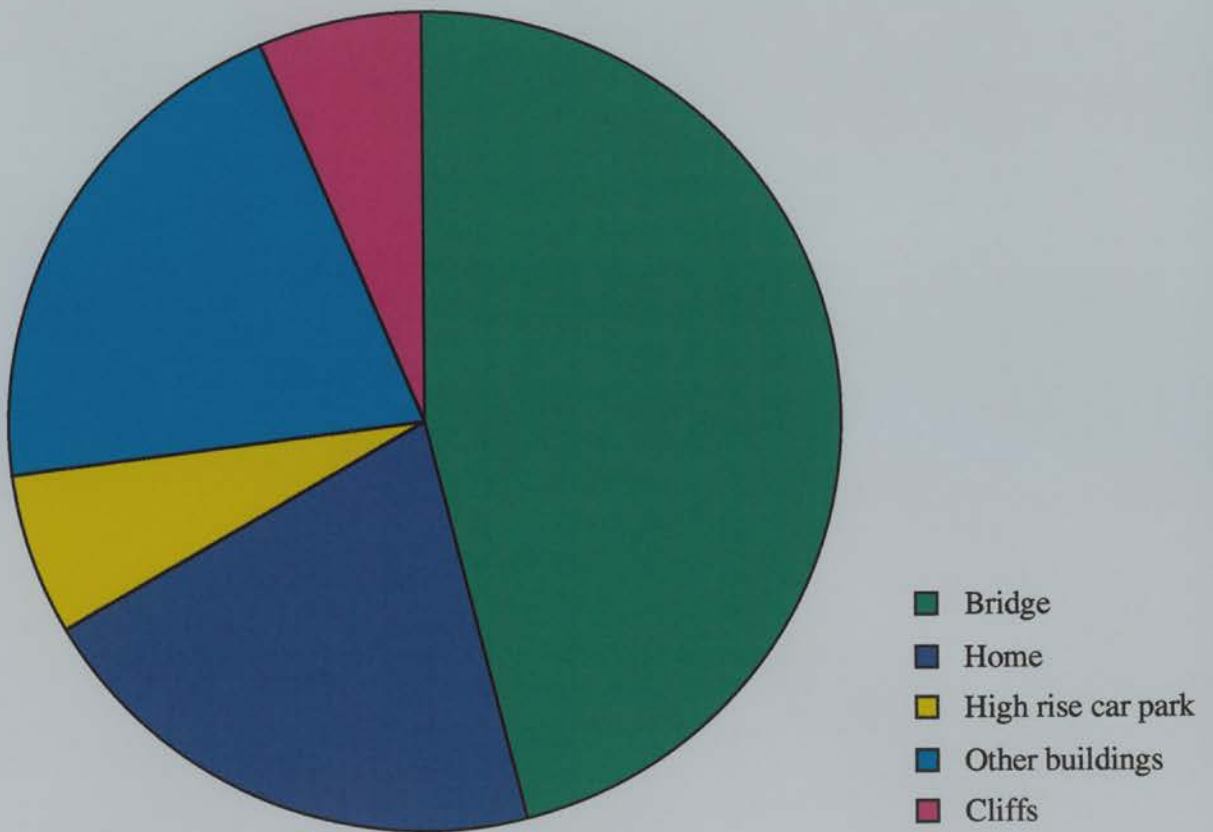


Table 4.2A - Apparent background to the suicides

Background	Number of deaths (total = 63)
Psychiatric illness	44
Relationship difficulties	6
Chronic illness	5
Alcohol related problems	2
Unemployment	1
Unable to cope with partner's death	1
Unclear	4

Figure 4.2(iii) - Suicidal high falls ISS

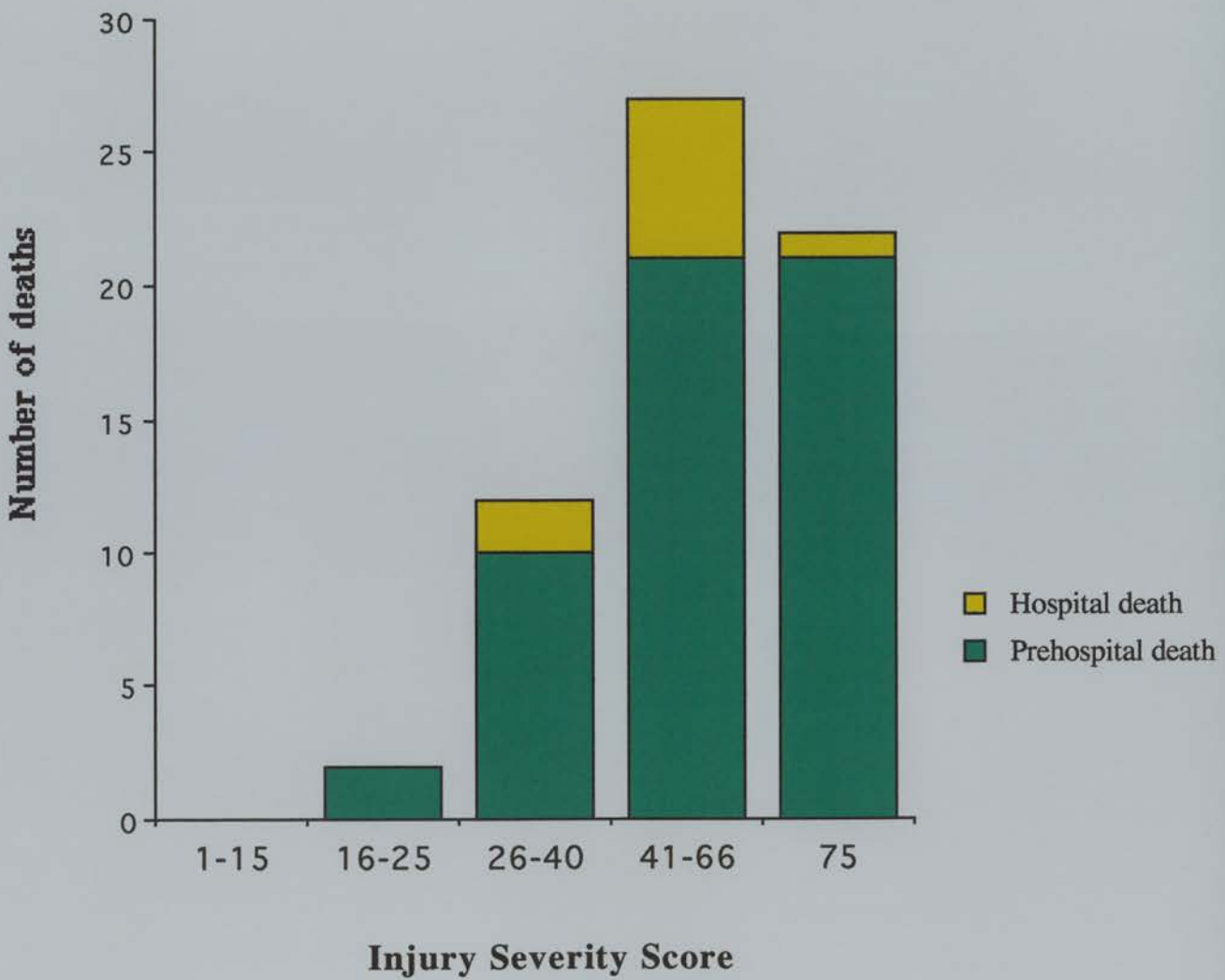
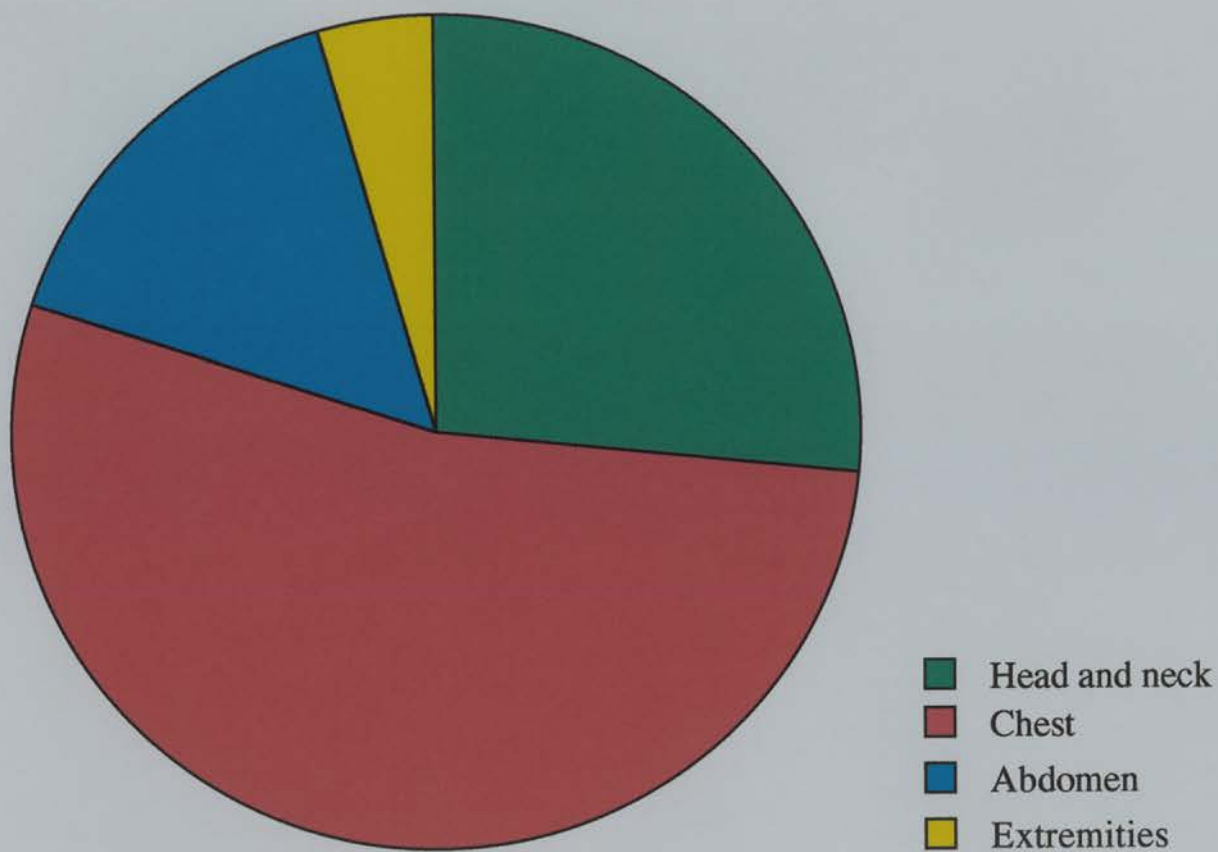


Table 4.2B - Suicidal high falls unsurvivable injuries (AIS=6)

Unsurvivable injury	Number of patients
Complete rupture thoracic aorta	10
Massive injury to brain / brainstem	8
Massive cardiac disruption	4
Transected upper cervical spinal cord	2

Includes four patients who had two separate unsurvivable injuries and one patient who had three separate unsurvivable injuries.

Figure 4.2(iv) - Body regions responsible for MAIS in suicidal high falls



Discussion

The scene of death after a high fall may understandably appear suspicious at first sight to investigating police officers who may, quite rightly, choose to involve the police surgeon (forensic medical examiner). Although a death may appear to be a suicide, the investigating professionals need to keep an open mind as homicide has been made to look like suicide in the past, particularly by bodies being thrown from a height after being killed. Examination of the scene of death should include exact recording of where the body came to lie to rest and its position (in particular the horizontal distance away from the building / bridge or cliff edge), as this may provide later clues as to the height from which an individual fell, and whether or not he/she fell, jumped or ran and jumped (Shaw & Hsu, 1998). It seems likely that the use of mathematical models and computer simulation will be developed sufficiently to assist with this (Lau et al., 1998; Sloan & Talbott, 1996). Later in the course of police investigations and autopsy, additional information may come to light which provides further clues as to the reason for the death. The pattern of injuries may enable a judgement as to whether an individual fell feet or head first (Goonetilleke, 1980).

This study has allowed an insight into suicidal falls (autokabalesis) in south-east Scotland. In keeping with previous studies from other parts of the world, the majority of those who died were male (Pounder, 1985; Copeland, 1989b; Hanzlick et al., 1990; Isbister & Roberts, 1992; Li & Smialek, 1994). The calculated rate of suicidal falls, representing less than a tenth of the national rate of suicides, is likely to be an under-estimate, since a number of other cases which might possibly have been

suicides were not included in this study (Department of Health, 1992; Secretary of State for Health, 1999). Analysis of the circumstances surrounding these cases did not enable a judgement to be made as to whether or not death was accidental or suicidal. Considering that in only a small proportion of the suicidal falls in the study a suicide note was left or someone had been told of the deceased's intention, it appears quite likely that a significant number of other deaths from falls were actually suicides. This contrasts with the situation with deaths from hanging, where it may be easier to reach a judgement as to whether or not the death was suicidal (Pounder, 1993).

Of the different ways in which suicidal individuals may try end their lives, many are relatively non-violent and do not involve disfigurement - these include hanging, drug overdose, carbon monoxide poisoning and plastic bag asphyxia (advocated by various groups interested in assisting "self-deliverance" - see chapter 4.6 (Humphry, 1991)). The violence and disfigurement involved in deaths from a high fall perhaps reflects the violent mental turmoil experienced by these individuals - this is in keeping with the fact that a high proportion had known psychotic illness. Indeed, this proportion is similar to that in a previous study of 32 suicidal falls from Glasgow (Isbister & Roberts, 1992).

The association between choosing a violent method of suicide and severe mental illness has been previously recognised (Pounder, 1985; Cooper & Milroy, 1994). Those who attempt suicide by jumping from a height appear to have greater suicidal intent than those who choose other methods (Hanzlick et al., 1990). Despite

this, it has also been suggested that the method of suicide chosen depends simply upon availability (Copeland, 1989b). Certainly in Edinburgh, the profusion of high buildings / bridges and relative lack of guns may partly influence the pattern of suicides.

The vast majority of suicidal falls resulted in death at the scene and most of these individuals were dead when found. It is thus clear that within this group there is relatively little for improved hospital treatment to offer in terms of saving lives. This is confirmed by an analysis of the pattern of injuries - all had ISS of more than 15 and many had injuries acknowledged to be unsurvivable (AIS = 6) (AAAM, 1990). Indeed, all those who survived to hospital had an ISS of more than 25, again underlining the little potential to such lives to be saved by improving hospital treatment.

The heights of many of the falls and the recognised association between height of fall and severity of injury probably explains the large number of unsurvivable injuries (Steedman, 1989). These unsurvivable injuries principally involved the thoracic aorta, heart, brain and brainstem, which is in keeping with data from previous studies (Goonetilleke, 1980). The most frequent unsurvivable injury was rupture of the thoracic aorta at the junction of the arch and the descending part, in keeping with the very rapid deceleration seen in other high energy impacts (Wyatt et al., 1997b).

Having established that there seems little potential to reduce the death rate from suicidal falls by improving hospital treatment, it is worth considering whether

some of the falls might have been prevented. Most of those who died had a past history of psychiatric problems, but these problems are relatively common amongst the general population, so do not present a small group of at-risk individuals to target. In any case, experts remain somewhat sceptical about being able to prevent suicide (Wilkinson, 1994). Only a small proportion of those who died appeared to have told someone about their suicidal intention, rendering prevention even more difficult. The sites chosen for the suicidal falls included two bridges which were used repeatedly (one in the city centre, the other on the outskirts of the city). As a result of the large numbers of suicides at these sites, they have been recently targeted with notices and SOS telephones to try to avert suicides. Their efficacy, however, remains to be proven and even if they are successful in reducing suicides at these sites, there may simply be an increase in suicides at other sites and/or by other methods.

4.3 Falls down stairs

Background

Falls are a relatively common cause of death following trauma in Scotland in all age groups (Registrar General for Scotland, 1996; Wyatt et al., 1996). The epidemiology and pattern of injuries in high (free) falls has been well documented, but in contrast, relatively little has been written about falls down stairs (Cicccone & Richman, 1948; Snyder, 1963; Goonetilleke, 1980; Maull et al., 1981; Scalea et al., 1986; Warner & Demling, 1986; Li & Smialek, 1994). As outlined in chapter 4.2, the pattern and severity of injuries sustained and the risk of death in a high fall is related closely to the height of that fall (Warner & Demling, 1986; Steedman, 1989; Lau & Viano, 1981; Risser et al., 1996).

Unlike free falls, which can be categorised according to the length of fall, falls down stairs cannot be easily classified, although there appears to be some potential for computer simulation to be of some assistance in this respect (Sloan & Talbott, 1996). The way that a body falls, slides or tumbles down stairs may depend upon the underlying cause of the fall. Whether the fall was caused by a stumble, a push, collapse following a medical condition or the influence of drugs or alcohol, may also have an effect upon the ability of an individual to protect himself / herself during the fall. This, in turn, may influence the nature and pattern of the injuries sustained.

In those falls which are unwitnessed, the actual length of the fall may be unclear. In addition, rather than depending solely upon the length of the fall, the nature and pattern of injuries sustained may depend also upon a variety of other factors, such as the steepness of the stairs and the surface landed upon (e.g. carpet, wood or stone). Injuries may also result during falls by impact against walls, banisters, other obstacles or ornaments on the stairs. This study was undertaken in order to examine the epidemiological and pathological findings in fatal falls down stairs, with particular reference to how deaths might be prevented.

Methods

Deaths following falls down stairs between 1992 and 1997 in Lothian and Borders regions of south-east Scotland were studied. Data sources included: police reports on these deaths, autopsy findings, post-mortem toxicology results, ambulance records, hospital case notes and the STAG database (see chapter 2). Deaths following falls which were not strictly down stairs, but which were free falls over banisters and down stairwells, were excluded from the analysis. The injuries sustained by all those who died after falls down stairs were scored according to the AIS (1990 revision), allowing ISS to be generated (see chapter 2.7).

Results

During the six years 1992–1997, there were 51 deaths (27 men, 24 women) following falls down stairs in south-east Scotland. The mean age of those who died was 68.9 years, with a range of 19–95 years as shown in figure 4.3(i). Forty-three fatal falls (84%) occurred within the victim's own home. The majority (27/43) of those who fell down stairs in their own homes lived alone, with 17 of these being aged more than 65 years.

Thirty (59%) of the falls were unwitnessed, the remaining 20 were witnessed or the noise of the fall was heard and responded to. Twenty-seven individuals (53%) died at the scene (including 24 after unwitnessed falls). Blood (obtained either at autopsy or on hospital admission) was sent for toxicological analysis on 28 patients where alcohol was suspected as being implicated in causing the fall. In 20 cases, blood alcohol levels exceeded 80mg/dl, the current legal limit for driving in the UK (figure 4.3(ii)).

Scoring according to the AIS (1990 revision) yielded ISS ranging from five to 75, with a median of 25 (as shown in figure 4.3(iii)). The four individuals who had ISS of less than 15 were found dead at the scene. Four of those who died had injuries acknowledged to be unsurvivable (AIS = 6, ISS = 75). The body regions responsible for the MAIS are shown in table 4.3A. Injury to the brain and/or spinal cord was responsible for the vast majority of the most severe injuries. In 47 cases, a single body region was responsible for MAIS; in four cases, two body regions were responsible.

Figure 4.3(i) - Age and sex of fatal falls down stairs

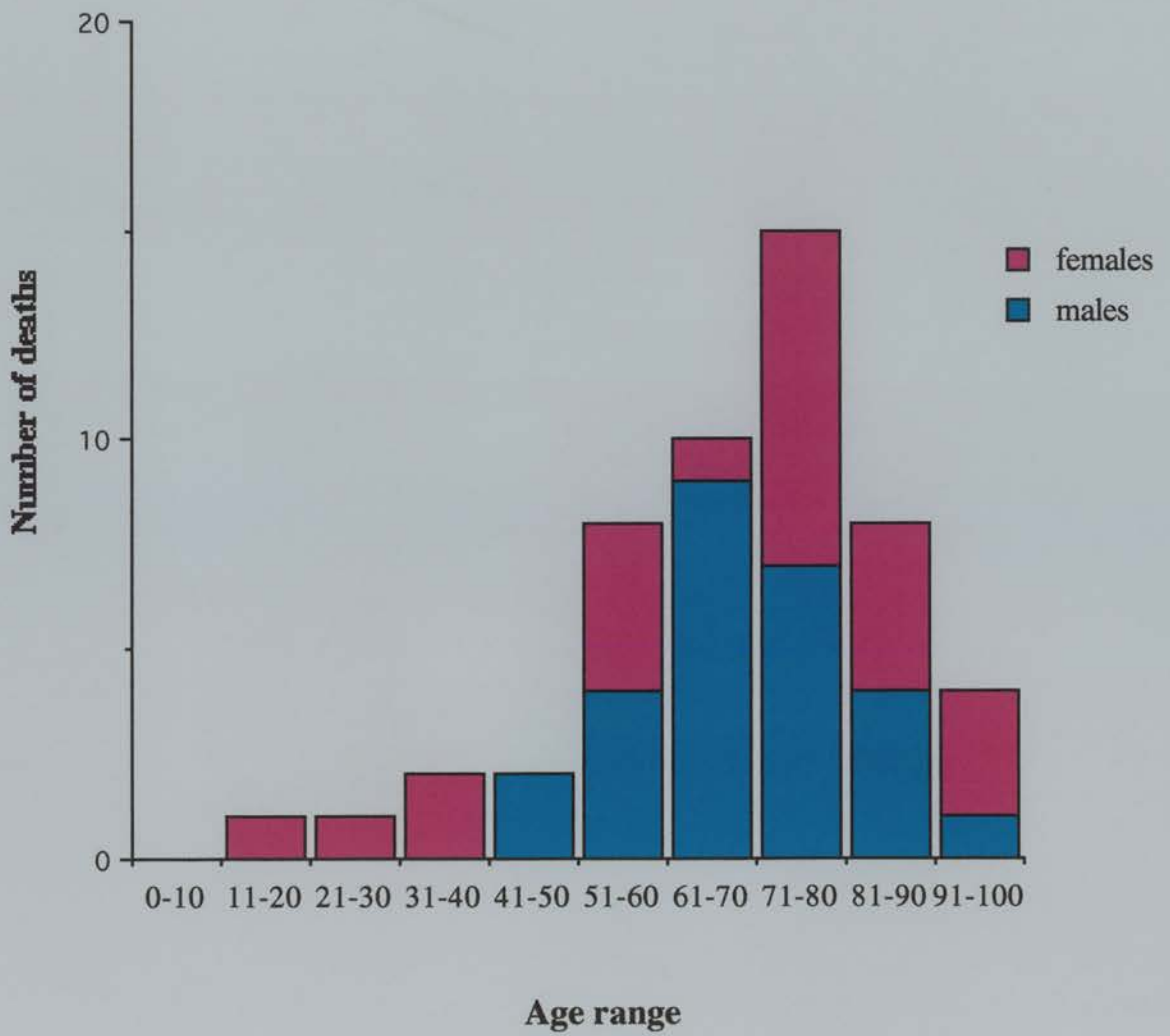


Figure 4.3(ii) - Blood alcohol levels after fatal falls down stairs

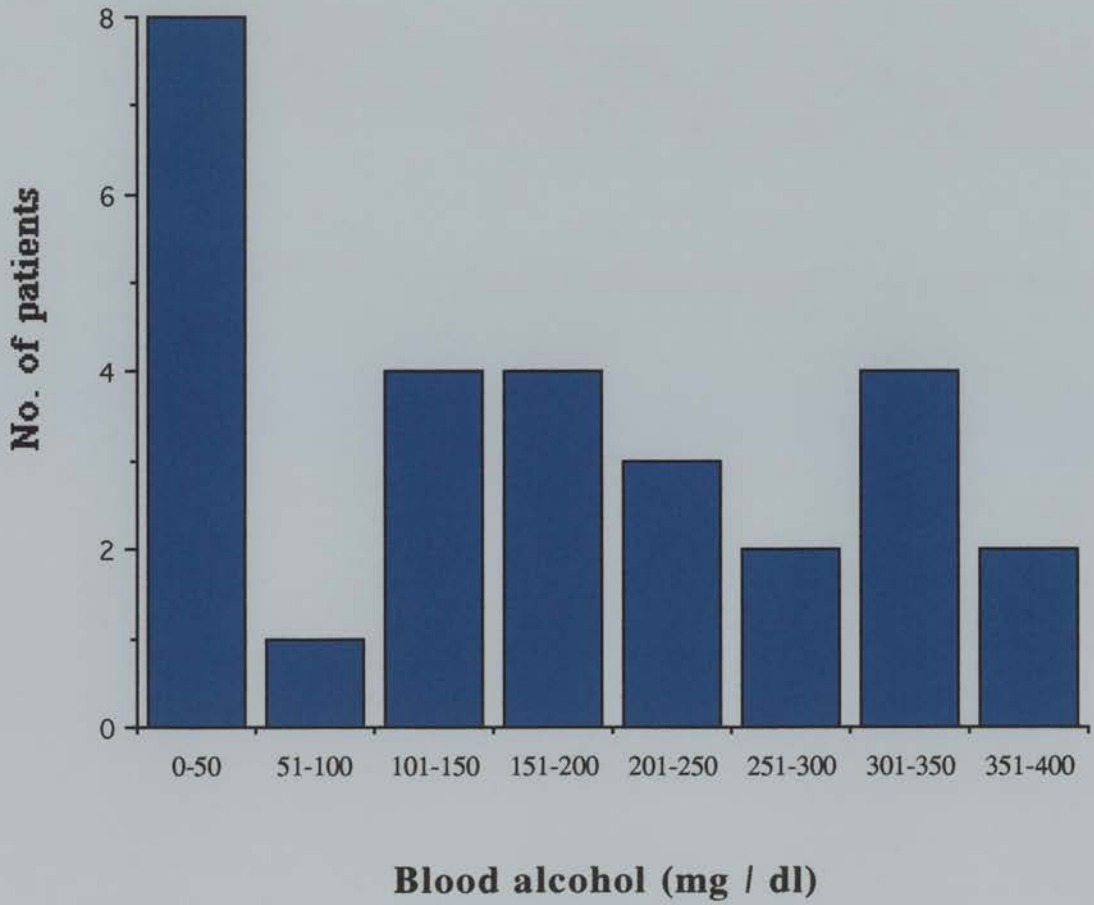


Figure 4.3(iii) - ISS of fatal falls down stairs according to place of death

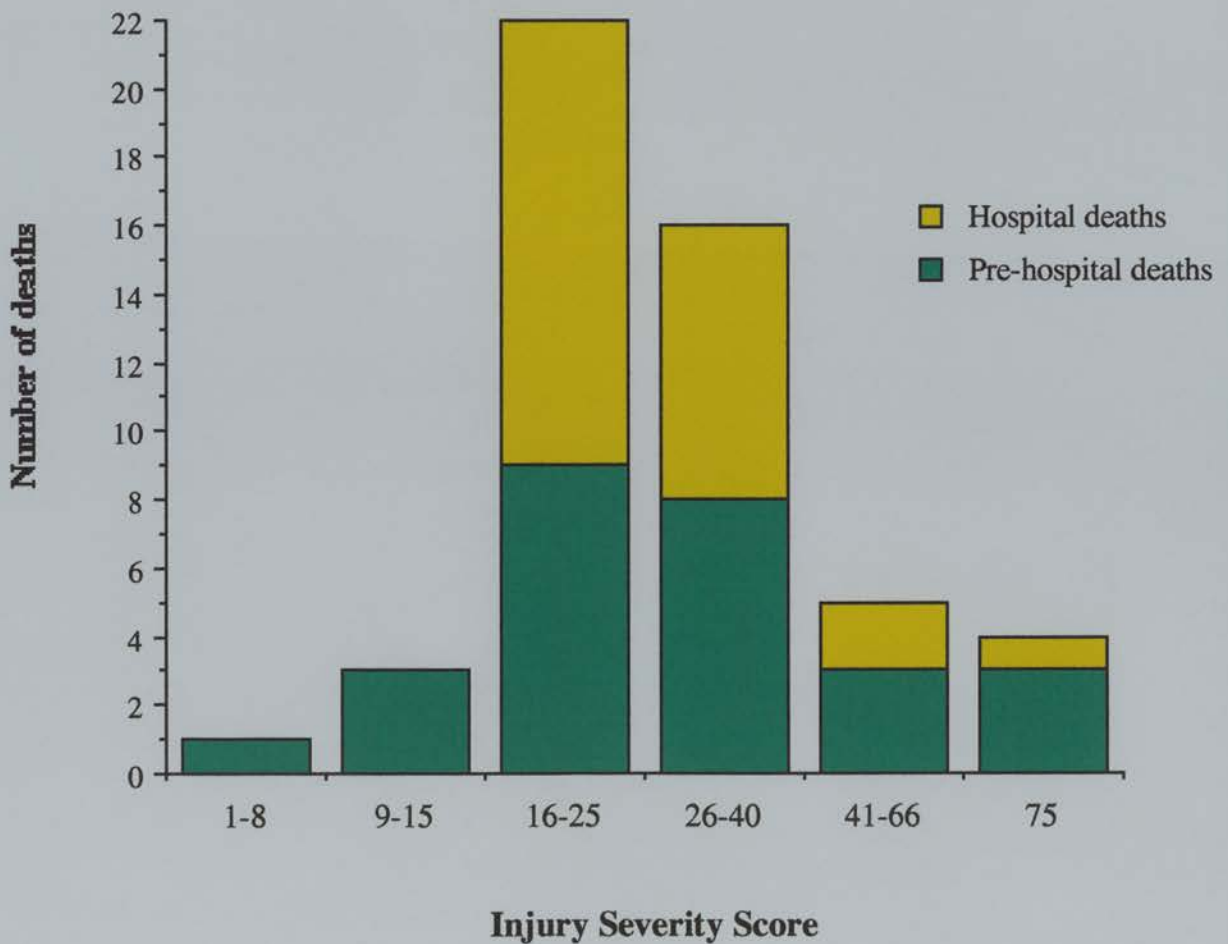


Table 4.3A - Injuries responsible for MAIS in fatal falls down stairs

Injury	Number of times responsible for MAIS
Brain / brainstem injury	35
Cervical spinal cord injury	8
Rib fractures with flail segment	6
Rib fractures without flail or internal injury	3
Liver injury	2
Rib fractures with massive haemothorax	1

Discussion

Roads are often considered to be places of potential danger: every year there are thousands of deaths on the roads in the UK (Department of Transport, 1996). In contrast, the familiarity of the home environment may result in a false perception of safety, but the results of this study demonstrate that amongst the potential dangers of many homes, are stairs. The problem of deaths following falls down stairs may be approached in a variety of ways. It is recognised that optimising stair design (including ensuring step-to-step uniformity) can minimise the risk of an injury occurring (Marpert, 1996). The most obvious long-term way of reducing the danger of falls on stairs would be to standardise their design in new buildings.

Although fatal falls down stairs are uncommon in the young, they are a particular problem of the elderly. The potential causes of falls is varied and includes one or more of the following: simple trips and slips, impaired balance, incoordination and immobility, postural hypotension (particularly secondary to medication), arrhythmias, cerebrovascular events and the effects of alcohol. In this study, in a large number of cases involving the elderly where alcohol was not implicated, the cause of the fall was unclear. This is because many individuals were unable to provide an account of what had happened, having been found dead at the scene after unwitnessed falls.

It is of concern that many elderly individuals had unwitnessed falls down stairs within their own homes and were then unable to summon help, thereafter succumbing to injuries which were eminently treatable. In keeping with falls in the

elderly in general, there may be a sound economic argument to devote more resources to prevention of falls down stairs (Englander et al., 1996). Accidents might be prevented by targeting the socially isolated at-risk elderly population and making the stairs at home safer (e.g. by improving or adding handrails or by ensuring stair carpets are non-slip and well fixed). In some circumstances, following a home assessment and consideration by a multidisciplinary trained team (comprising doctors, nurses, occupational therapists and social workers) (Rivara et al., 1997a), it may be appropriate to seriously consider moving some elderly people to a safer home environment without stairs. It seems inevitable that whilst elderly people continue to live with stairs in their homes, accidents will continue to occur. Those at risk might also benefit from alarms which are designed to activate after falls, thereby allowing earlier emergency treatment in the event of a fall.

Alcohol has been implicated in contributing in some way in many forms of trauma and death, both in the UK and elsewhere (Committee on Trauma Research, 1985; Hain et al., 1989; Cherpitel, 1993; Honkanen, 1993). Alcohol was heavily implicated in causing many of the falls. In this situation, the combination of increasing age (with attendant mobility problems) and acute alcohol intoxication renders stairs very dangerous. Having contributed to causing falls, acute alcohol intoxication may have rendered individuals prone to more serious injuries, by adversely affecting any natural tendency to protect themselves as they landed. In addition, chronic alcohol abuse (with associated liver disease) may also have

predisposed to increased bleeding after injury. In this fashion, a relatively minor traumatic insult may have been transformed into a life-threatening problem.

The fact that the majority of deaths occurred in the pre-hospital setting may be more a reflection of the fact that many of those injured in the falls were alone and unable to summon help (because of pre-existing mobility problems, other medical problems and/or the effects of alcohol), than solely as a result of the severity of their injuries. Indeed, only four individuals (7.8%) had injuries recognised as being incompatible with life (AIS = 6, ISS = 75). This contrasts with those who died following other forms of trauma, where a significant proportion have injuries recognised to be untreatable (see chapters 3.1, 3.2, 3.3, 4.2, 4.5, 4.7, 5.2; Wyatt et al., 1996; Wyatt et al., 1997a).

Given that there may be a tendency for an unsteady person on the stairs to topple head-first downstairs during a fall, it is perhaps unsurprising that injury to the head and neck was responsible for the most severe injuries in the majority of patients. These head injuries, even if only relatively minor, may in the presence of alcohol intoxication or pre-existing mobility / medical problems have effectively prevented an injured person to obtain assistance after an unwitnessed fall. In addition, it has been suggested that the combination of acute alcohol intoxication and minor head injury may occasionally result in sudden death, perhaps by a direct effect on the brainstem cardio-respiratory centres (Ramsay & Shkrum, 1995). This perhaps partly explains the deaths after injuries which might not ordinarily be considered to be life-threatening. Another important factor is that the elderly have a much higher

risk of death after a relatively minor injury because of reduced physiological reserve (DeMaria, 1993). This appears to be particularly true in extreme old age (more than 80 years) (Shabot & Johnson, 1995).

Analysis of the pattern and severity of injuries amongst those who died after falling down stairs did not reveal any obvious potential for injury reduction measures targeted at specific injuries. The approach recently proposed to reduce the risk of hip fracture in the elderly by using hip padding to soften the “landing surface” in the event of a simple fall, does not extrapolate well as far as falls down stairs are concerned (Lauritzen et al., 1993). Apart from removing any obvious obstacles on the stairs which might cause additional injury in the event of a fall, attempts to make the surface landed upon safer are unlikely to be helpful. Instead, efforts would be better directed at trying to prevent falls occurring in the first place, as outlined above.

4.4 Drownings

Background

Drowning is a significant cause of death from trauma in south-east Scotland (Wyatt et al., 1995; Wyatt et al., 1997a). The most obvious way to reduce the death rate would be to prevent the drowning accident or incident. An additional way would be to improve the rate of successful resuscitation after a near drowning incident. It has been recognised for many years that cold water submersion is compatible with long-term survival, even when the period of immersion is relatively long (Kvittingen & Naess, 1963; King, 1964; Domínguez de Villota et al., 1973; Siebke et al., 1975; Young et al., 1980; Pearn, 1985; Edwards et al., 1990; Kemp & Sibert, 1991). As a result, guidelines for resuscitation of individuals who are found immersed in water stress the importance of prolonged resuscitation using advanced life support techniques (Oakes et al., 1982; Pearn, 1985; Resuscitation Council (UK), 1998; American Heart Association, 1992; Quan, 1993; Golden et al., 1997; Steedman et al., 1997). This study examines the extent to which those individuals who died following drowning in south-east Scotland were resuscitated.

Methods

The circumstances of deaths due to drowning in Lothian and Borders regions of south-east Scotland during the seven years 1991 - 1997 were studied. A variety of data sources were used, including: Procurator Fiscal records, autopsy reports prepared by the Forensic Medicine Unit, police, ambulance and hospital records.

Results

There were 95 deaths (69 males, 26 females) from drowning amongst people aged between five months and 87 years. Considering that the population studied was 0.83 million, the rate of drownings per year was 1.6 per 100,000 (Office of Population Censuses and Surveys, 1993). The majority of drownings occurred outside in water which was mostly relatively cold (table 4.4A). Twenty-two (23%) of the drowning incidents were witnessed, 73 (77%) were unwitnessed.

The bodies of 28 individuals were recovered within one hour of them having been last seen alive, 13 having had witnessed accidents, 15 having had unwitnessed accidents (table 4.4B). Eleven of these 28 individuals were either never resuscitated or were declared dead at the scene, despite being known to be alive within the past one hour.

Six individuals (mean age 50 years) were not resuscitated at the scene by the police or other emergency services, despite being known to be alive within the

previous hour (table 4.4C). A further five individuals (mean age 38 years) were initially resuscitated by police and/or ambulance crews, but were declared dead by a doctor at the scene within one hour of last being known to be alive. None of these five patients benefited from doctor-led advanced life support or rewarming techniques (table 4.4D).

Table 4.4A - Sites of drowning incidents

Location	Number of drownings
Sea	35
Flowing freshwater (rivers, streams)	26
Still freshwater (reservoirs, lochs, canals, ponds)	19
Bathtub	15
TOTAL	95

Table 4.4B - Resuscitation of the drowning victims.

<u>Individuals known to be alive within one hour prior to being found</u>	
No resuscitation at scene, not taken to hospital	6
Resuscitated initially at scene, declared dead within 1 hour at scene	5
Resuscitated initially at scene, taken to hospital for further resuscitation	17
<u>Individuals not known to be alive within one hour prior to being found</u>	
No resuscitation at scene, not taken to hospital	57
Resuscitated initially at scene, declared dead within 1 hour at scene	6
Resuscitated initially at scene, taken to hospital for further resuscitation	4

Table 4.4C - Details of the six individuals who were never resuscitated, despite being found within an hour of last being alive.

No.	Age	Sex	Immersion witnessed?	Location	Time last seen alive
1	47yrs	M	witnessed	reservoir	15mins
2	21yrs	M	unwitnessed	sea	25mins
3	47yrs	M	witnessed	sea	40 mins
4	55yrs	F	unwitnessed	sea	40mins
5	59yrs	F	unwitnessed	canal	45mins
6	71yrs	M	unwitnessed	river	50mins

Table 4.4D - Details of the five individuals who were initially resuscitated, but declared dead at scene within an hour of being alive.

No.	Age	Sex	Immersion witnessed?	Location	Time last seen alive
1	74yrs	F	unwitnessed	bath tub*	41mins
2	19yrs	M	witnessed	sea	42mins
3	27yrs	M	witnessed	sea	42mins
4	16yrs	F	unwitnessed	bath tub*	44mins
5	56yrs	M	witnessed	sea	56mins

* Water temperature at the time of submersion unknown.

Discussion

The rate of drowning deaths was 1.6 per 100,000 per year in south-east Scotland - less than that in many other countries (O'Carroll et al., 1988; Gamero et al., 1997). The pattern of deaths from drowning in south-east Scotland is different from that in other parts of the world (Plueckhahn, 1984; O'Carroll et al., 1988; Gamero et al., 1997): the climate and low sea temperatures do not encourage outdoor recreational swimming. This is reflected in this study in that there were no deaths in relatively warm water of private swimming pools, although in keeping with data from elsewhere in the UK, a minority of deaths did occur in the home, all involving the bath-tub (Nowers, 1999). The vast majority of drownings occurred in various outdoor waters, where the relatively cold Scottish water temperatures may have offered the submerged victims a degree of cerebral protection.

The majority of those who died of drowning in south-east Scotland received no form of resuscitation when found. In many cases, this appears to have been entirely appropriate, particularly where a body had been recovered having been immersed in water for several hours or days. However, it is a cause for some concern that six individuals received no resuscitation, despite the fact that the immersion incident resulting in drowning occurred only recently. It is also worrying that five individuals who did initially receive basic life support at the scene after a recent drowning incident, were declared dead by a doctor at the scene within an hour of that incident, without receiving the potential benefits of either advanced life support techniques or a prolonged attempt at resuscitation. In the cases of those individuals

whose accidents occurred in the sea or rivers, the resuscitation attempt may have usefully included an attempt at core rewarming (Kemp & Sibert, 1991; Norberg et al., 1992; Golden et al., 1997; International Liaison Committee on Resuscitation, 1997).

The data presented in this study demonstrate that members of the emergency services, including doctors, are failing to both initiate prehospital resuscitation and to continue this to hospital for victims of near drowning. These results suggest that there may be some potential to reduce the death rate from drownings in south-east Scotland by improving prehospital resuscitation and continuing this to hospital. Police officers, other members of the emergency services and the public should be educated about the need to commence basic life support on a body found in water when there is a possibility of a recent drowning incident. Similarly, doctors (particularly general practitioners) attending the scenes of such incidents need to be aware of the potential benefit of prolonged resuscitation and hospital-based advanced life support resuscitation measures (Oakes et al., 1982; Pearn, 1985; American Heart Association, 1992; Quan, 1993; Golden et al., 1997; Steedman et al., 1997; Resuscitation Council (UK), 1998).

4.5 Stabbings

Background

The rate of homicide in Scotland (and the rest of the UK) remains relatively low when compared with the USA (Trunkey, 1983; Committee on trauma research, 1985; Sauaia et al., 1995; Scottish Office Statistical Bulletin, 1995; Wyatt et al., 1996). In the USA, the use of guns accounts for most homicides (Committee on trauma research, 1985; Centers for Disease Control, 1995; Sauaia et al., 1995; Crandall et al., 1997), arousing considerable concern and resulting in calls for restrictive measures to be introduced (Violence prevention task force, 1995; Powell et al., 1996). In contrast, in Scotland, the use of guns is responsible for only a small proportion of homicides (9 out of 111 (8%) in 1994), whereas the use of knives and other sharp instruments account for a large proportion (58 out of 111 (52%) in 1994) (Scottish Office Statistical Bulletin, 1995). Indeed, the use of knives in assaults in Scotland in recent years has aroused understandable concern (Scottish Office Statistical Bulletin, 1997a).

In order to examine the relative risks of death after assault with a knife and to investigate why some patients die whilst others survive, it is necessary to study a complete population (including both deaths and survivors). Sharp force injuries may be classified by those trained in forensic medicine according to the relative length of the wound compared with its depth ("stab" wounds, "slash" wounds). Although

distinguishing between stab wounds and slash wounds may have important clinical implications, this is not always an easy task for practitioners with no forensic training (Lettington, 2000). Slash / chop wounds are uncommon in most parts of the world, although they are seen relatively frequently in Malaysia, where traditional sickle-shaped knives are standard weapons amongst Triad gang members (Ong, 1999).

Methodology

All individuals who were admitted to hospital or who died before reaching hospital having been assaulted with a sharp implement within the city of Edinburgh and its associated suburbs (approximate population 0.5 million people) during the period February 1992 - December 1996 were identified and studied using Forensic Medicine and STAG records. Only those injuries which appeared to have resulted from assaults were studied: self-inflicted trauma was not included in this analysis. All those patients who presented to hospital following a knife injury were admitted for treatment (and included in this study) where there was any possibility of significant injury to an underlying structure or organ. Patients who presented with minor, superficial skin wounds which did not require hospital admission were not included in the study. It is possible that some individuals may have survived after sustaining deep penetrating injuries and choosing not to seek medical attention - such individuals, if any, would not have been included in this study.

Data was collected for those individuals who died following stabbing from a variety of sources, including ambulance and hospital records, police and Procurator Fiscal reports, autopsy and toxicological records. Data was also collected prospectively by STAG on all patients who were brought to hospital in Edinburgh after being stabbed (see chapter 2.6) and for some patients, by the hospital based flying squad, "Medic One" (see chapter 8.3). Injuries sustained by both survivors and those who died were scored according to the AIS (AAAM, 1990), from which ISS and where relevant, Ps were calculated (Baker et al., 1974; Boyd et al., 1987; chapter 2.7).

Results

During the study period there were 20 deaths (17 males, 3 females) following assault by stabbing. A further 100 individuals (96 males, 4 females) survived stabbings, following admission to hospital. In most cases, although the weapons were described by those injured as being knives, these weapons were never recovered and compared with the wounds. Additionally, in some cases, the victim did not see the weapon. It is therefore possible that a proportion of the injuries attributed to knives were actually caused by other sharp implements.

The age profile of survivors compared with non-survivors is demonstrated in figure 4.5(i). The age range found in both categories was similar: survivors 15–62

years, non-survivors 19–58 years. The peak in frequency of non-fatal stabbings in the 25–29 year category, is mirrored by the deaths.

The ISS of all those stabbed is shown in figure 4.5(ii). The majority (83%) of survivors sustained injuries with an ISS of less than 15 (an ISS of more than 15 is an accepted definition of major trauma (STAG, 1995)). In contrast, 95% of the fatal cases scored an ISS greater than 15. Comparing the groups using a Chi square test revealed that significantly more non-survivors had sustained “major trauma” ($\chi^2 = 273.3$ and $p < 0.0001$).

Twelve of the 20 individuals who died after being stabbed showed no signs of life when found, three died at the scene or in transit to hospital (within “Medic One”) having been found alive and only five patients reached hospital alive, but died later. Calculation using TRISS methodology revealed all five individuals to have probabilities of survival (Ps) of less than 50% - all were therefore classed as “expected” deaths (table 4.5A). By contrast, the 100 survivors of stabbing assaults had probabilities of survival ranging from 4.0% to 99.9% and included two “unexpected survivors”.

Details of those who died, together with their most severe injuries, are shown in table (table 4.5A). Eight individuals had cardiac injuries acknowledged to be unsurvivable (AIS = 6, ISS = 75). Apart from the obligatory presence of an “attacker”, half of the 12 ‘potentially survivable’ assaults occurred when the victim was otherwise alone and unable to summon immediate help. This may have severely compromised their chances of survival.

The maximum Abbreviated Injury Scale scores (MAIS) were recorded for all 120 cases, according to which of the six standard anatomical regions within which they fell. This data has been displayed graphically in figure 4.5(iii). The seventh category of 'combined' represents cases where more than one body region scored the same MAIS. There were significantly more chest injuries responsible for the MAIS score in the fatal group, than the non-fatal ($\chi^2 = 39.1$ and $p < 0.0001$). The anatomical component 'head and neck' was also over-represented in the fatal category when compared to the non-fatal one ($\chi^2 = 102.6$ and $p < 0.0001$). No fatalities resulted from injuries where the MAIS score occurred in the anatomical regions of the face, extremities or external.

Figure 4.5(i) - Ages of non-fatal and fatal stabbing victims

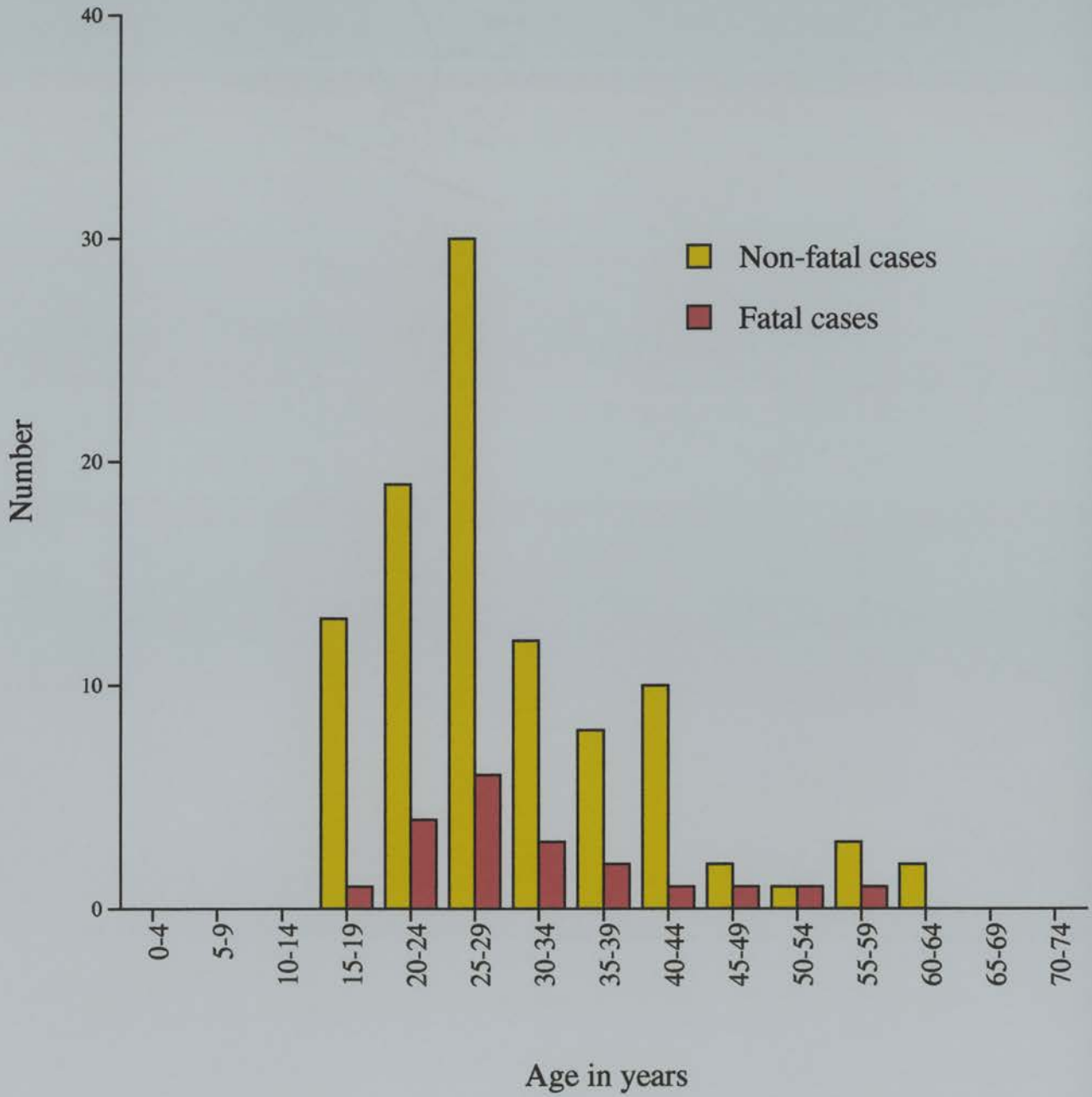


Figure 4.5(ii) - Outcome of stabbings by ISS

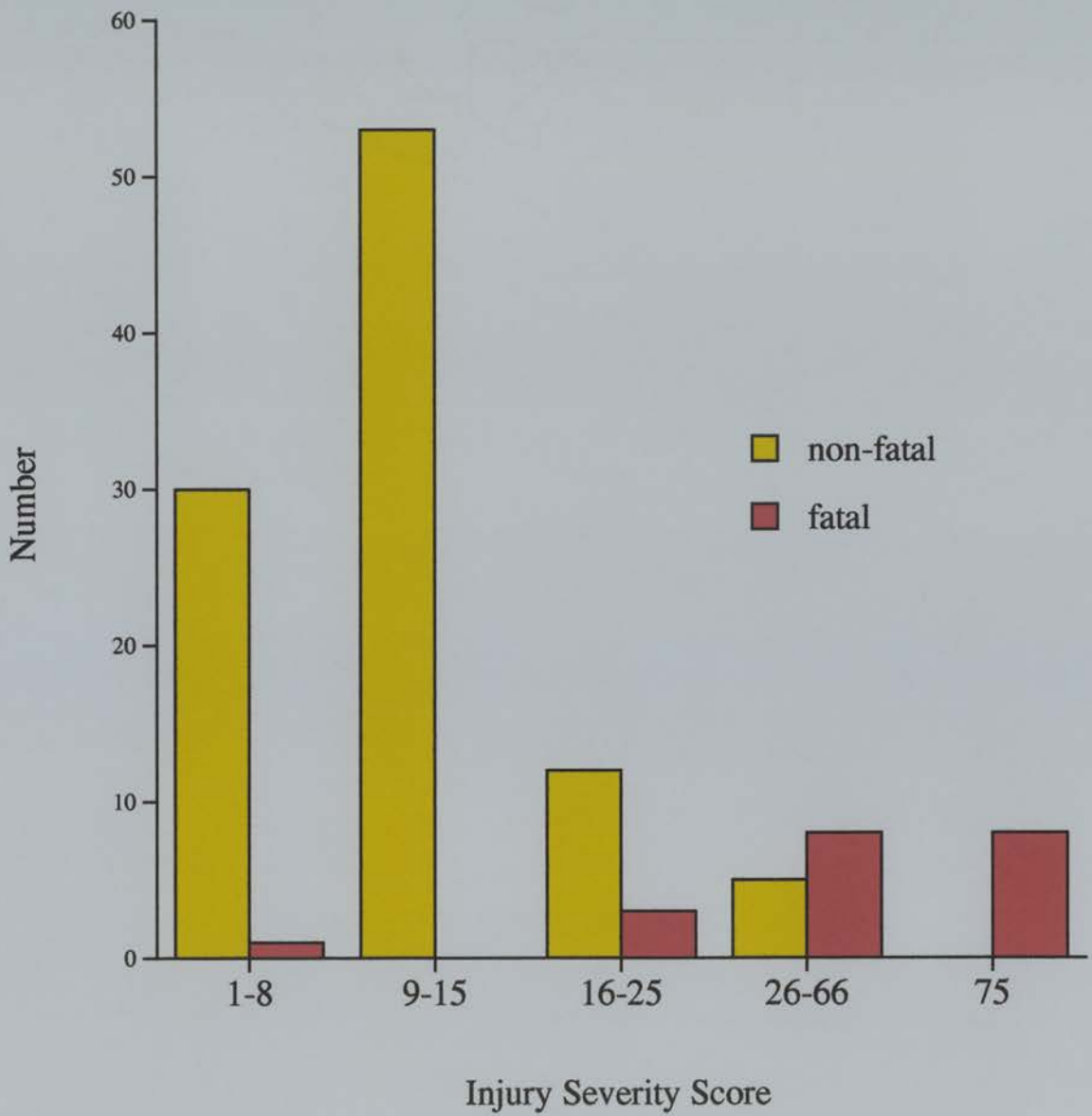


Table 4.5A - Details of the fatal stabbings

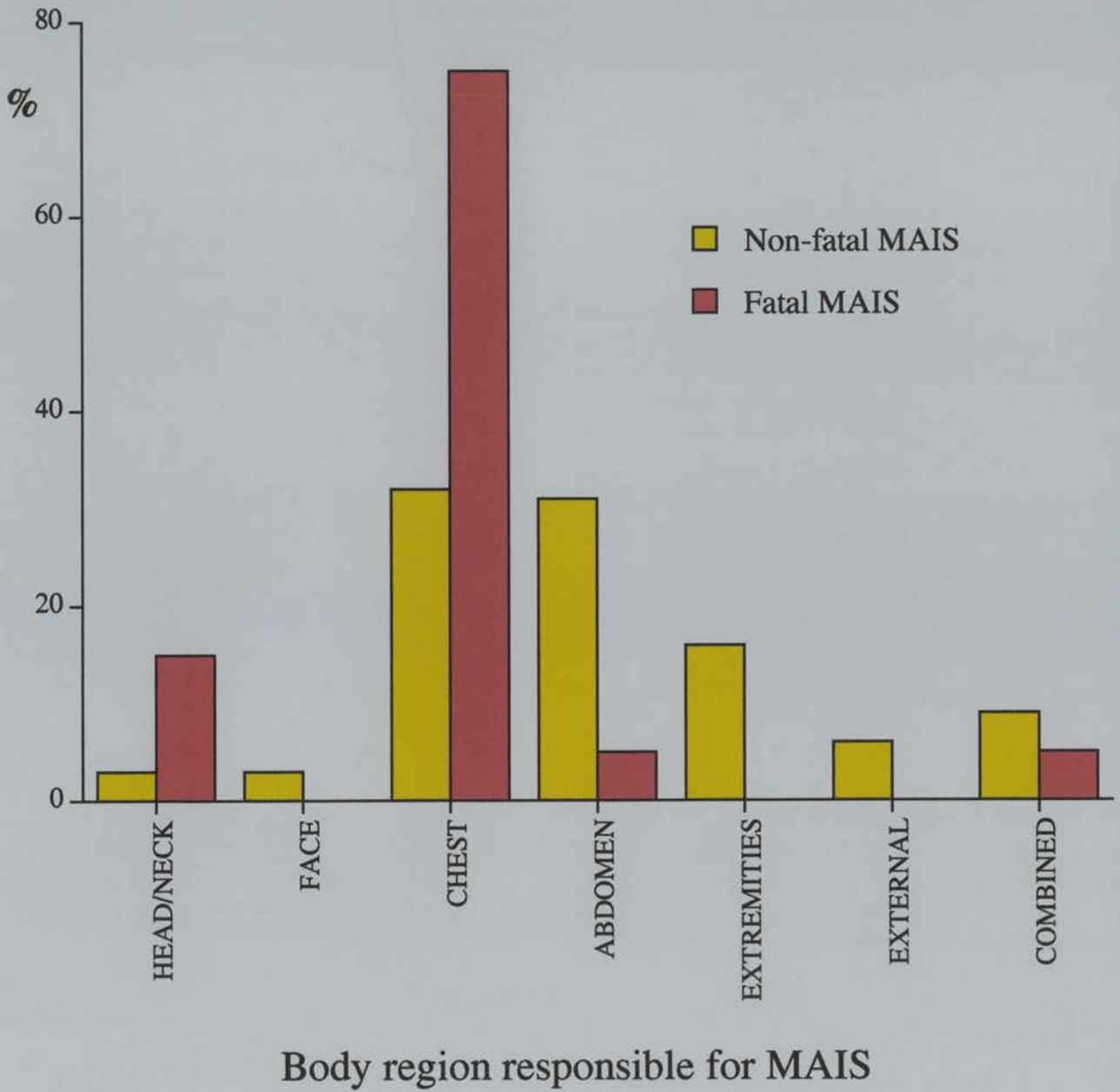
No.	Age (yrs)	Sex	Blood alcohol (mg/dl)	Most severely injured body region	MAIS	ISS	Ps (%)	Place of death
1	22	F	0	Chest	6	75	-	Scene
2	25	F	0	Chest	6	75	-	Scene
3	25	M	?	Chest	6	75	-	Scene
4	25	M	235	Chest	6	75	-	Scene
5	31	M	66	Chest	6	75	-	Scene
6	33	M	355	Chest	6	75	-	Scene
7	36	M	0	Chest	6	75	-	Scene
8	48	M	(232*)	Chest	6	75	-	Scene
9	34	F	354	Head / neck	5	45	-	Scene
10	50	M	360	Chest	5	42	-	Scene
11	21	M	(166#)	Chest	5	42	0.4	Hospital
12	57	M	(357*)	Chest	5	38	-	Scene
13	41	M	0	Chest	5	35	-	Scene
14	19	M	38	Chest	5	27	-	Medic 1
15	22	M	0	Chest	5	26	1	Hospital
16	29	M	145	Chest	5	26	1	Hospital
17	29	M	171	Head / neck	4	21	-	Medic 1
18	22	M	216	Abdomen	4	17	4	Hospital
19	39	M	145	Chest	4	17	4	Hospital
20	27	M	?	Head / neck	2	5	-	Scene

* = vitreous sample

= urine sample

? = toxicology result not available

Figure 4.5(iii) - Body regions responsible for MAIS in stabbings



Discussion

Data from A&E departments and from police records in Europe demonstrate that most interpersonal violence takes the form of blunt trauma rather than penetrating trauma (Shepherd et al., 1990; Ström et al., 1991; Brink et al., 1998). Despite representing only a small proportion of the total, the potential risk to life following the penetrating trauma is considerable. In keeping with (unwelcome) developments in other parts of the world, the rate of homicides in Scotland has risen in recent years, with stabbings being the most common mechanism (Scottish Office Statistical Bulletin, 1995; Milroy & Ranson, 1997).

Deaths which appeared to have followed self-inflicted knife injuries were excluded from this analysis as outlined above. A previous study from Yorkshire and Humberside found that 19% of suspicious deaths involving "cutting and piercing" represented suicides, approximately half of which were "self-stabbings" (Start et al., 1992). It must be acknowledged that it is possible that some of the injuries included in this study which were believed to be assaults were actually self-inflicted injuries. In view of the detailed investigation which inevitably accompanies a suspicious death it seems more likely that any mis-classification involved individuals who survived the injury.

Many more males were stabbed than females during the study period. In keeping with this male predominance, the vast majority of those who died were male. Similarly, the majority of victims of stabbings were aged between 15 and 34 years.

These findings are consistent with data from elsewhere (Hunt & Cowling, 1991; Rouse, 1994; Sidhu et al., 1996).

Many of those who died after being stabbed had alcohol present in their bloodstream, urine or vitreous fluid at the time of death. The corresponding data for those who inflicted the fatal stabbings or those who survived being stabbed is not complete, since blood alcohol levels are not routinely collected on patients presenting alive to A&E. However, it is recognised from previous studies that alcohol plays a role in a significant proportion of violent crimes (Ormstad et al., 1986; Strom et al., 1991; Wright & Kariya, 1997; Borges et al., 1998; Treno et al., 1998). In addition to its potential role in causing someone to be stabbed, alcohol may also play a part in determining both the injuries received and whether those injuries resulted in survival or death. Firstly, alcohol may render a person less capable of defending himself or escaping quickly from a potentially violent situation. Secondly, having been stabbed, alcohol may blur an individual's perception of the severity of their injuries and adversely affect their initial response in terms of seeking urgent medical attention - data from previous studies show that some individuals are capable of considerable activity despite receiving fatal injuries (Thoresen & Rognum, 1986; Juvin et al., 1999). Thirdly, the influence of alcohol may reduce a stabbed person's ability to apply pressure and limit bleeding from an external wound. Fourthly, the presence of alcohol may limit the ability of someone to call for emergency medical help - this is particularly pertinent in those cases where there were no witnesses to the stabbing incident.

Figure 4.5(ii) demonstrates that the outcome after a stabbing injury (in terms of survival or death) can be explained to a large extent by the severity of the injuries sustained. All except one of those who died had injuries consistent with major trauma (ISS greater than 15). Most of the fatal injuries involved stabbings to the chest or neck - these body regions being implicated significantly more frequently in causing MAIS than other body regions. These results confirm those of previous studies which emphasise the role of injury to the heart and major vessels in causing death after stabbing (Thoresen & Rognum, 1986; Rouse, 1994).

All five patients who died having reached hospital with signs of life had very low predicted probabilities of survival, indicating that medical intervention had little chance of saving their lives. Indeed, the fact that there were two unexpected survivors, but no unexpected deaths, amongst those stabbed is an indication that the hospital system for treating such patients is working efficiently. As a result, there is little evidence for any potential to "save lives" through improved hospital treatment. This contrasts with previous studies which identified deficiencies in trauma management in many UK hospitals (Royal College of Surgeons of England, 1988; Yates et al., 1992). Table 4.5A does demonstrate that 12 of the 20 individuals who died had potentially survivable injuries, but most failed to reach hospital alive. For example, the one patient who died with an ISS of less than 15 sustained a neck injury which resulted in pre-hospital exsanguination. Unfortunately, if a stabbed person is unable to immediately summon help, either because of the severity of the injuries or

because of the effects of alcohol or drugs, he/she may not receive prompt medical attention. This may result in death from injuries which were potentially survivable.

The need for rapid transfer to hospital after serious penetrating injury to allow definitive surgical intervention is becoming increasingly recognised and is beginning to influence pre-hospital and hospital care (Stern et al., 1993; Bickell et al., 1994; Jacobs, 1994; Lerer & Knottenbelt, 1994). The application of pressure and bandages in the pre-hospital setting to stop haemorrhage from briskly bleeding skin wounds is of obvious benefit. Whilst such simple measures may be performed rapidly, other interventions, particularly the insertion of intravenous cannulae and administration of intravenous fluids are time-consuming (Rainer et al., 1997). These pre-hospital interventions may be counter-productive in several respects. Firstly, increasing the blood pressure by giving intravenous fluids may result in an increased rate of haemorrhage; secondly, the additional time delay may increase the amount of haemorrhage before definitive treatment and thirdly, the administration of crystalloid fluids may adversely affect coagulation (Sampalis et al., 1993; Rainer et al., 1997; Yagmur et al., 1999, Brazil & Coats, 2000). These arguments particularly apply in the urban environment of this study, where transfer times to hospital are relatively short. The current philosophy for the pre-hospital care of victims of penetrating trauma embraces the concept of "limited resuscitation", which aims to maintain a lowered blood arterial pressure (typically a mean arterial blood pressure of 45 mmHg) thereby avoiding prehospital exsanguination and immediate death (Doucet & Hall, 1999).

Preventing the death of someone who has been the victim of a stabbing by improving treatment is a laudable aim. However, even having been successful, the surviving victim may have to contend with both physical and psychological sequelae (Lowenstein, 1999). Perhaps the best approach to adopt to try to reduce the number of stabbing deaths would be to try to limit the carrying of sharp weapons. Combined efforts by the media and emergency medicine physicians to attempt to limit the number of knives carried on the streets have been tried in other parts of Scotland (Bleetman et al., 1997). These attempts resulted in a certain amount of success in the short term, with a large number of knives being collected by the police and an associated decreased number of patients presenting to hospital following stabbings (Bleetman et al., 1997). Despite this, it seems inevitable that some assaults by “stabbing” will continue in Scotland in the foreseeable future.

4.6 Plastic bag asphyxia

Background

Polythene (or plastic) bags became widely available in the UK in the late 1950's. Being lightweight, sturdy, waterproof and non-porous, their future as "carrier bags" was assured. However, within a short time of their introduction, accidental death associated with plastic bags (plastic bag asphyxia) was reported in children who had placed their heads within a plastic bag (Anon., 1959). As a result, preventative measures were introduced, including giving warnings and publicising the dangers, together with adding small perforations to some plastic bags. First reports of deaths of adults in both suicidal and accidental autoerotic circumstances appeared soon after (Johnstone et al., 1960; Hunt & Camps, 1962).

In the last thirty years, plastic bag asphyxia, although uncommon, has become an increasingly recognised entity seen in a wide variety of situations. These include autoerotic and drug misadventures, other accidents (mainly involving children), suicides and some homicides, including infanticide. Traditionally, the term "asphyxia" (Greek = breathlessness) is used to describe a hypoxic event. In plastic bag asphyxia, this could occur due to a decreasing oxygen concentration in the available inspired air and/or due to physical obstruction of the mouth and nose. In the past, it was proposed that the latter mechanism resulted from the plastic bag becoming electrically charged and adhering to the face, the phenomenon being aided by

condensation of water vapour (Johnstone et al., 1960). However, it is now believed that death ensues much faster in many cases and that these physical phenomena do not have enough time to occur. It has also been postulated that when a plastic bag is placed over the head, the sympathetic nervous system is rapidly stimulated (especially if the plastic is in close contact with the face), resulting in arrhythmias, including ventricular fibrillation (Knight, 1996). This latter explanation would account for a lack of pathological signs (petechial haemorrhages, facial congestion, oedema and cyanosis) associated with more typical true mechanism asphyxial deaths (Knight, 1996; Jaffe, 1994).

The lack of typical asphyxial autopsy findings and of other positive findings in plastic bag asphyxia makes it a very difficult positive diagnosis to make, without a detailed examination of the locus, preferably with the bag still in situ. Even with all this information, it can be difficult to differentiate between suicide and an autoerotic accident, particularly if the scene of death has been disturbed before the police had been called. An autoerotic accident is suggested by the presence of other sexual aids, pornographic material, states of undress or cross-dressing, a “self-rescue” mechanism and a past history of autoerotic behaviour in the same individual (Uva, 1995).

Whilst the use of plastic bags in the context of autoerotic asphyxia is usually associated with a degree of secrecy, there has been much publicity and controversy surrounding its use as a tool in self-assisted suicide. Much of this followed publication of Derek Humphry’s book: “Final Exit: The Practicalities of Self-Deliverance and Assisted Suicide for the Dying” in 1991 (Humphry D, 1991). This

book, which has sold more than one million copies world-wide, recommended plastic bag asphyxia in combination with the taking of a sedative (preferably in an overdose), together with alcohol, as an effective method of “self-deliverance”. This method was promoted because it is non-violent, easy to plan and resource and is very effective.

Medical problems associated with a variety of confined spaces are being increasingly recognised (Greenberg, 1989). The inside of a plastic bag represents an extreme example of a confined space. With this background in mind, this study was undertaken to examine the incidence, circumstances and pathological findings of plastic bag asphyxia in south-east Scotland.

Methods

Cases of plastic bag asphyxia amongst the defined population of 830,000 (Office of Population Censuses and Surveys, 1993) in the Lothian and Borders region of south-east Scotland between 1984 and 1998 (inclusive) were identified from records of the Forensic Medicine Unit. Relevant police reports, autopsy findings and toxicological results were examined.

Results

During the 15 years of the study, 14,560 autopsies were performed in the Forensic Medicine Unit and 30 deaths (0.2%) were attributed to plastic bag asphyxia. These 30 deaths comprised 20 males and ten females, with an age range of 13–81 years and a mean of 50 years (table 4.6A). Two deaths occurred in people aged less than 21 years. The first involved a 20 year old male student who died accidentally whilst using a plastic bag to inhale chloroform “recreationally” from soaked paper tissues lying within the bag. This was a common practice for this chemistry student, despite numerous warnings from friends and his GP. The second “young” death involved a 13 year old girl who, fearing that she was pregnant, used plastic bag asphyxia in combination with inhaled aerosol deodorant to apparently commit suicide after her parents had found out about her fears and had confronted her. There were no accidental deaths from plastic bag asphyxia in children.

The mean male age was 45 years and the mean female age was 61 years. Twelve of the male decedents were single, five were married, two separated and one widowed. Three of the females were single, two were married and five were widows. Six of the males were unemployed, seven were employed, four were retired and three were students. None of the females were currently in employment, five were retired, four were “housewives” and one was a schoolgirl.

Twenty-five of the incidents (83%) occurred within the decedent’s own home (20 in the bedroom and five in the lounge). The remaining five incidents occurred respectively in a hotel (two), a hospital, a workplace laboratory and open moorland.

Although the Scottish legal system does not require an “official” decision to be made and publically announced as to whether each death is the result of an accident or suicide, careful examination of the circumstances revealed that 27 appeared to be suicides and three to be accidents. The three unintentional deaths comprised the 20 year old male who had been inhaling chloroform recreationally (as described above) and two individuals who died during autoerotic incidents. One of the autoerotic incidents involved a 21 year old male who was discovered naked next to pornographic literature, having died with a plastic bag secured over his head containing aerosol glue spray. The other involved a 35 year old male who was found wearing a diving wetsuit with a plastic bag around his head and a plastic tube in his rectum.

The identified background to the 27 apparent suicides is shown in table 4.6B. Of the six who committed suicide due to being unable to cope with sudden recent changing social circumstances, four had financial difficulties (one of whom had also recently lost a close relative), one had recently separated from his spouse and one was the 13 year old schoolgirl outlined above. The two decedents with a terminal illness suffered from bronchial carcinoma and APUD type carcinoma with liver metastases respectively.

The 16 individuals with a known psychiatric illness included ten treated for depression, five treated for other psychotic illness, and one for an anxiety disorder. Ten of the 27 individuals who committed suicide had attempted suicide in the past: three of these left a suicide note and recently discussed their suicidal intentions with

family and/or friends, two left a note without discussing it and a further four had discussed their suicidal intentions. Of the 17 decedents who had not attempted suicide in the past, three had left a suicide note, three had discussed it recently and one had both left a note and discussed suicide.

Three of the 27 individuals who committed suicide were members of the Voluntary Euthanasia Society of Scotland and one other individual had “self-deliverance” literature found in the house. Two of these individuals had depression, one had bronchial carcinoma and one had severe crippling arthritis.

The method of plastic bag asphyxia used by the decedents is detailed in table 4.6C. Autopsy toxicological studies revealed a number of substances to be acting as associated factors. Eleven had alcohol detectable in their blood: seven with levels less than 80mg/dl, three with levels 81–160mg/dl, and one with a level greater than 240mg/dl. Eight individuals had therapeutic blood levels of prescribed drugs (benzodiazepines, carbamazepine, mianserin hydrochloride) and one had a blood level of amitriptyline within the fatal range. The decedents who inhaled aerosol deodorant and lighter fluid respectively, were found to have a mixture of volatile compounds in the blood closely similar to those anticipated from the substances inhaled. Chloroform was found in one case.

Fifteen of the decedents were found by relatives, five by friends, three by policemen called in by friends / relatives because of concern about the deceased, and seven by other witnesses. On being found, 24 of the decedents were obviously dead and no resuscitation was attempted. In six cases, cardiac resuscitation was attempted,

but in only one case was this attempt continued by the emergency services to hospital, where the individual failed to respond. Two individuals were in a sitting position when found, the remainder were lying down (one appeared to have fallen). In two cases advanced decomposition had occurred and one of these bodies required to be dentally identified.

External and internal petechial haemorrhages were found in five cases (the conjunctivae were affected in three cases, the eyelids in one, other areas of the face in one, the neck in one and the lungs in two). Facial congestion was noted in three cases and in one case the tongue was protruding and had been clasped between the teeth. Four of the decedents who had secured the plastic bag around their necks were found to have a blanched or abraded mark at this site.

Nine of the decedents had either clinical or pathological evidence of pre-existing disease which might have altered their initial response to a hypoxic insult. Six individuals had moderate - severe coronary artery atheroma (two had previously had myocardial infarction) and three individuals had significant respiratory disorders (asthma, chronic bronchitis and bronchial carcinoma respectively).

Table 4.6A - Age and sex distribution amongst plastic bag suicides

Age range (years)	Number of males	Number of females	Total
0-10	0	0	0
11-20	1	1	2
21-30	5	0	5
31-40	4	0	4
41-50	3	0	3
51-60	2	4	6
61-70	4	1	5
71-80	0	3	3
81-90	1	1	2
TOTAL	20	10	30

Table 4.6B - Background to the plastic bag suicides

Background	Number
Chronic psychiatric illness	16
Unable to cope with sudden recent changing social circumstances	6
Terminal illness	2
Chronic debilitating illness	2
No obvious background factor	1

Table 4.6C - Method used in the 30 plastic bag asphyxia deaths

Method of asphyxia	Number
1 plastic bag loose over head, not secured	10
1 plastic bag over head, secured around neck	9
2 or more plastic bags, secured around neck	5
1 plastic bag containing aerosol deodorant, secured around neck	2
1 plastic bag containing nitrogen gas, secured around neck	1
1 plastic bag containing butane, secured around neck	1
1 plastic bag containing aerosol glue spray, secured around neck	1
1 plastic bag loose over head, containing chloroform	1

Discussion

This study revealed the rate of death due to plastic bag asphyxia to be relatively low at 0.24 deaths per 100,000 population per year. In contrast to the few previously published reports, in this series the number of males who died exceeded the number of females (Martinez et al., 1993; Haddix et al., 1996). A bimodal peak in age distribution was observed, and in keeping with a previous study, there was evidence of one peak comprising mainly young adult men and another mainly of older women (Martinez et al., 1993).

At autopsy, only a small number of cases were found to have some of the classic signs of asphyxia. Petechial haemorrhages are commonly seen following asphyxial deaths (Jaffe, 1994), and may even follow cardiopulmonary resuscitation (Hood et al., 1988), yet were only seen in five decedents in this series. In the absence of positive autopsy evidence, the diagnosis of plastic bag asphyxia relies heavily on the circumstantial evidence obtained at the locus of death. Failure of the attending police officers and doctors to scrutinise the scene may well result in the wrong conclusion being reached. This is particularly true when trying to differentiate between "accident" and suicide, especially in cases of autoeroticism or associated drug ingestion. This underlines the important role of toxicology - the autopsy is not complete without checking blood, urine and bronchial fluid for alcohol, solvents and other suspected drugs. Similarly, it is important to remember the possibility of solvents and drugs within the plastic bag itself, which requires to be packaged in an airtight container and sent for toxicological examination. In addition to encountering

problems trying to distinguish accidents from suicides, the possibility of homicide needs to be considered. It must also be remembered that on rare situations, the scene of death may be tampered with to attempt to make a suicide or homicide appear to be an accident (Henry, 1996).

Evidence suggestive of suicide includes the finding of a suicide note and recently voiced suicidal intentions. Careful examination revealed that the vast majority of the deaths in this series appeared to be suicides. Alcohol and drugs did not appear to play a significant role in most of these deaths, with only three of those who died having blood alcohol levels in excess of 80mg/dl and only one having overdosed (with a potentially fatal blood level of amitriptyline).

Plastic bag suicides, in keeping with suicides in general, are difficult to predict and hence prevent (Wilkinson, 1994). In contrast to a previous study from the USA, but in keeping with previous data from the UK, psychiatric illness was implicated more frequently than physical illness in plastic bag suicides in this study (Martinez et al., 1993; Haddix et al., 1996). Prominent "at risk" factors included: psychiatric illness (particularly depression and where individuals had talked of suicide), unemployment, social isolation and bereavement.

The potential role of media publicity in increasing the number of plastic bag suicides has been recognised for many years (Church & Phillips, 1984). Following the introduction of Derek Humphry's "Final Exit" in 1991, an increase in the number of plastic bag suicides was observed, first in New York and later in the remainder of the USA (Humphry, 1991; Marzuk & Hirsch, 1984; Marzuk et al., 1994). Despite this

and extensive references to assisted suicide on the internet and in the media (Dobson, 1999), only four of the decedents in this study were known to either have “self-deliverance” literature or to have had contact with “self-deliverance” organisations. It would therefore seem that in south-east Scotland, at least, the attention given to the subject of assisted suicide in the press is not associated with a large number of deaths.

There does not appear to be an easy way to prevent either accidental or suicidal death from plastic bag asphyxia. In the same way that it is not possible to prevent suicidal high fall deaths by denying access to high bridges, buildings and cliffs (chapter 4.2; Wyatt et al., 2000a), neither is it feasible to prevent deaths by restricting the availability and use of plastic bags. However, there appears to be scope to make plastic bags safer by more widespread use of perforations. The majority of decedents in this study appeared to have been dead for some time, such that in only six cases was resuscitation attempted. None of the plastic bag asphyxial deaths in this series appeared to have been witnessed, underlining the limited potential for lives to be saved through improved resuscitation.

Despite earlier theories, including obstruction of external respiratory orifices by the plastic bag becoming electrically charged, the mechanism of death in plastic bag asphyxia remains unclear (Johnstone et al., 1960). The tape used to secure the plastic bags in some of the cases resulted in minor blanching of the neck, but none showed the imprinting typical of hanging deaths (Luke et al., 1985). The asphyxial mechanisms believed to be involved in hanging (external compression of neck blood

vessels, larynx / trachea or carotid sinus / vagus nerve) do not therefore appear to play a part in plastic bag asphyxia (Luke et al., 1985; Cooke et al., 1995). Instead, hypoxia may result from oxygen being used up within the confined space of the plastic bag (Balding et al., 1995; Watanabe & Morita, 1998). In the presence of pre-existing cardiac or respiratory disease (nine cases in this study), a lowered inspired concentration of oxygen may result in more rapid onset of significant tissue hypoxia, with early fatal results.

Postural asphyxia did not contribute to any deaths in this study, but inhaled drugs may have played a part. In one case, the flow of nitrogen gas into the bag may have physically displaced oxygen, thereby reducing the inspired oxygen concentration (Wagner et al., 1992). Aerosol hydrocarbons may have had a similar effect, but also have directly caused a cardiac arrhythmia (Gunn et al., 1989; Avis & Archibald, 1994; Rohrig, 1997). Similarly, the volatile anaesthetic agent chloroform (implicated in one case) can cause death by causing arrhythmias, or by depression of respiration from a direct effect on the medullary respiratory centre (McGee et al., 1987; Nashelsky et al., 1995; Byard et al., 2000a). The relative absence of ingested drugs to assist in plastic bag asphyxia suicide in this study contrasts with data from Switzerland where the use of certain drugs (notably barbiturates) are advocated by the "Exit Association" (Giroud et al., 1999). Interestingly, unlike the situation in the UK, providing assistance to commit suicide is not punishable by Swiss law, provided that it is not motivated by financial or other gain. This may account for a greater

number of suicidal deaths associated with self-deliverance organisations in Switzerland (Giroud et al., 1999; Beecham, 2000).

Accidental deaths associated with plastic bags, but unrelated to drug use or autoerotic behaviour, are very uncommon. Previous reports of these accidental deaths have largely involved young children (Anon., 1959; Sturner et al., 1976; Baker & Fisher, 1980; Flobecker et al., 1993; Nixon et al., 1995). In this study, there were no such deaths, which probably reflects effective injury prevention measures, including public awareness campaigns, the inclusion of perforations and warnings on many “carrier bags”.

There were three apparently unintentional deaths amongst adults in the series presented. One resulted from the use of inhaled chloroform, the other two were autoerotic, one of which involved inhaled glue spray. The potential role of plastic bags in autoerotic behaviour has been recognised for many years (Johnstone et al., 1960) and the use of drugs inhaled from plastic bags during autoerotic activity has also been previously reported (Gowitt & Hanzlick, 1992). This behaviour is almost invariably highly secretive in nature, rendering prevention of accidental death from the use of plastic bags extremely difficult (Uva, 1995).

4.7 Motorcyclists

Background

Travel by motorcycle in the UK is associated with much higher rates of injury and death than those associated with travel by car, bus, lorry and bicycle (Department of Transport, 1996). In order to help determine which measures which are most likely to be effective in preventing death following motorcycle collisions, it is necessary to examine the nature and severity of injuries sustained by motorcyclists. In addition, an examination of the treatment provided and the timing of death allows conclusions to be drawn regarding the potential to “save lives” by improving prehospital and hospital treatment.

Methods

All those individuals who died as a result of motorcycle collisions within Lothian and Borders regions of south-east Scotland between 1987 and 1997 were identified and studied, using a variety of data sources: ambulance, police, hospital, STAG, Forensic Medicine, Procurator Fiscal and Registrar General records (chapter 2; STAG, 1995). Injuries were scored according to AIS (1990 revision), enabling ISS to be calculated (chapter 2.7; Wyatt et al., 1998a).

Results

Number and timing of deaths

During the eleven years under consideration there were 59 deaths, comprising 51 motorcyclists, seven pillion passengers and one side-car passenger. Fifty-eight of the 59 who died were wearing a helmet at the time of the collision. The majority of deaths occurred at the scene of the collision, with only 12 individuals reaching hospital alive (table 4.7A).

Injury scoring

Scoring according to the 1990 revision of the AIS yielded ISS ranging from 25–75 (table 4.7B). Twenty-five individuals had injuries acknowledged to be unsurvivable (AIS = 6, ISS = 75), all of whom died at the injury scene. The 25 patients with unsurvivable injuries had a total of 30 injuries which are currently considered untreatable (three patients had sustained more than one unsurvivable injury). These 30 injuries predominantly involved the thoracic part of the aorta, the brainstem and high cervical spinal cord (table 4.7C).

Four of the six possible AIS “body regions” were responsible for MAIS scores, but in keeping with the pattern of unsurvivable injuries, overall, the MAIS scores were found predominantly within the body regions of “head and neck” and “chest” (table 4.7D).

Table 4.7A - Place of death amongst motorcycle fatalities

Place of death	Number
Died at scene of injury - found dead	39
Died at scene of injury - found alive	6
Died in transit to hospital	2
Died in hospital	12

Table 4.7B - ISS according to place of death of motorcyclists

ISS	Prehospital death	Hospital death	Total
1-15	0	0	0
16-25	1	0	1
26-40	9	5	14
41-66	12	7	19
75	25	0	25

Table 4.7C - Unsurvivable injuries amongst motorcyclists

Body region	Injury	Number
Head and neck	Transection of upper cervical cord	4
	Skull fracture with brainstem laceration or massive crush	5
	Fracture / dislocation at atlanto-occipital joint with brainstem laceration or massive crush	4
	Complete decapitation	1
Chest	Transection of thoracic aorta at junction between arch and descending portion	10
	Transection of ascending aorta	1
	Ruptured left ventricle	3
Abdomen	Massive liver destruction	2

Table 4.7D - MAIS scores according to body region

AIS body region	Number of times responsible for MAIS
Head and neck	38
Chest	28
Abdomen	10
Extremities	3
Face	0
External	0

Discussion

Analysis of the timing of deaths revealed that most of the deaths of motorcyclists after road traffic collisions occurred before they reached hospital. It therefore follows that the potential to reduce the death rate amongst motorcyclists in south-east Scotland by improving hospital treatment appears to be somewhat limited. Further evidence supporting this conclusion is that no motorcyclist died in hospital with only minor injuries - all had an ISS of at least 26 (an ISS of greater than 15 being an accepted definition of "major trauma", with an associated mortality of at least 10% - STAG, 1995). Furthermore, analysis of the quality of care given to patients with major injuries in south-east Scotland (measured in terms of actual survival compared with expected survival using prospectively collected data in TRISS analysis) revealed that this region compares favourably with other parts of the UK (Yates et al., 1992; STAG, 1998).

The pre-hospital deaths can be divided up into those motorcyclists who were found dead, those who were found alive but died at the scene and those who died in transit to hospital. The results demonstrate that the majority of those who died before reaching hospital were dead when found. This means that there appears to be limited potential to significantly reduce the death rate by improving pre-hospital medical attention. Findings of previous studies have been conflicting as to whether or not lives could be saved in severely injured victims by simple airway opening manoeuvres (e.g. jaw thrust manoeuvre, manual removal of debris from the oropharynx, use of the recovery position) being performed by a member of the

public without equipment at the scene of injury (Yates, 1977; Hussain & Redmond, 1994). Certainly, in this study none of the individuals appeared to have died as a result of simple airway obstruction which would have been amenable to straightforward airway opening manoeuvres.

Twenty-five motorcyclists (42%) had sustained injuries which are acknowledged to be unsurvivable (AIS = 6, ISS = 75). The most common unsurvivable injury involved complete transection of the thoracic aorta. Although some debate remains about the exact pathophysiological mechanism responsible for this lesion, with various different theories proposed, this injury is invariably associated with rapid deceleration and the application of a large amount of blunt force (chapter 6.2; Keen, 1972; Sevitt, 1977a; Crass et al., 1990). Despite the fact that all except one motorcyclist were wearing specially designed protective helmets, unsurvivable injuries to the brain, brainstem and upper cervical spinal cord occurred on 14 occasions. Similarly, despite helmet use, the head and neck was the most severely injured region in those motorcyclists who died with potentially survivable injuries (ISS <75).

The results of this study tend to point towards better injury prevention as the principal way forward to reduce the death rate amongst motorcyclists, rather than through improvements in hospital treatment. Measures designed to prevent collisions will be most effective if they are successful in permanently altering the driving behaviour of both motorcyclists and other road users.

Improvements in motorcycling equipment (helmets, clothing) and motor vehicle design may be successful in reducing the severity of injuries sustained by motorcyclists. The design of certain motorcycles has been implicated in causing specific serious injuries (e.g. large petrol tanks causing perineal injuries) (Shiono et al., 1990; de Peretti et al., 1994). It is possible that the future design of motorbikes may assist with a significant reduction injuries sustained in a collision. Examples are the addition of leg protectors and air bags (Harms, 1993; Rivara et al., 1997b). Air bags incorporated into the top of a petrol tank would aim to alter the trajectory of a motorcyclist in the event of a collision, with the aim of enabling the motorcyclist to be thrown over the top of the vehicle it had collided with, rather than into the side of it. Such a modification would be most useful in the event of a head-on collision. Similarly, it is possible that future modifications of the design of cars and other vehicles might render them more “friendly” to the motorcyclist in the event of a collision. The general scope of such developments would be to make the exterior of cars less unyielding when hit, thereby lessening the very rapid deceleration which appears to be an important factor in causing many of the serious and life-threatening injuries to motorcyclists. This philosophy has already been strongly advocated as a way of reducing injuries to pedestrians struck by cars (Mackay, 1994).

Injuries to the head and neck continue to be responsible for a large proportion of the fatal injuries, despite the widespread use of appropriate helmets. It is therefore not surprising that attention will continue to be focused upon continuing use of helmets and further improvements in helmet design (Doyle et al., 1995; Rivara et al.,

1997b). Although it is likely that there will be future modifications in both construction materials and design, it is difficult to see how some of the most severe injuries might be prevented in the event of a collision, considering the tremendous forces involved in very rapid deceleration from high speed. "Accident" prevention and injury reduction measures are clearly of great importance, yet it seems that the inherent vulnerability of motorcyclists almost inevitably predisposes them to a greater risk of injury in the event of a collision than a properly restrained car driver travelling at an equivalent speed.

4.8 Pedestrians

Background

The first fatal road traffic collision in the UK occurred in 1896 when a female pedestrian stepped off the kerb and was hit by a “speeding” Roger-Benz car, resulting in her death from a head injury (Porter, 1998). Similarly, the first motor vehicle related fatality in the USA occurred in New York in 1899 and involved a pedestrian (National Committee for Injury Prevention and Control, 1989). During the intervening century, the death toll amongst pedestrians in both the UK and the USA has been considerable (Committee on trauma research, 1985; Department of Transport, 1996; Scottish Office, 1997).

Methods

Pedestrian deaths following road traffic collisions in south-east Scotland were prospectively studied over a seven year period (1992–1998 inclusive) in a collaborative project involving STAG, the Forensic Medicine Unit in the University of Edinburgh and A&E in the Royal Infirmary of Edinburgh. Pedestrian deaths in road traffic collisions were identified using above sources and from the records of the Registrar General. The circumstances of the fatal collisions were obtained from detailed police reports, including Accident Investigation reports (chapter 2.3).

Clinical data was collected prospectively by STAG on injured pedestrians who survived to reach hospital (chapter 2.6). Autopsies were performed in a standardised fashion and samples of blood and other body fluids were taken at the time of autopsy and subjected to toxicological analysis (chapter 2.8). Injuries sustained were scored according to AIS (1990 revision) enabling ISS to be calculated (chapter 2.7).

Results

145 pedestrians (79 male, 66 female) died following collisions with motor vehicles. The vehicles involved are shown in table 4.8A. Given the known population of south-east Scotland of 830,000 (Office of Population Censuses and Surveys, 1993), the rate of pedestrian deaths was 2.5 per 100,000 population per year. The ages of the pedestrians who died is shown in figure 4.8(i), which shows that 76 (52%) were aged more than 60 years.

The vast majority of the pedestrian deaths appeared to have been unintentional (“accidental”), but six appeared to have been suicides and one a homicide. Judgements made on the basis of all available information as to who was principally at fault in causing the road traffic collisions implicated the pedestrians themselves in the majority of cases. Detailed circumstances of the deaths are shown in table 4.8B. Autopsies were performed on 143 pedestrians (99%). Toxicology

revealed 37 pedestrians had recently consumed alcohol and/or drugs, 26 having blood alcohol levels greater than 80mg/dl (the UK legal limit for driving).

59 pedestrians (41%) were found dead or died at scene, 3 (2%) died in transit, 83 (57%) survived to reach hospital alive, but later died. Figure 4.8(ii) shows that there was a considerable spread of ISS, although 135 (93%) had ISS of greater than 15. Of the 34 pedestrians with an ISS of 75, there were 49 unsurvivable injuries as shown in table 4.8C.

Table 4.8A - Vehicles involved in collisions resulting in pedestrian deaths

Vehicle involved	Number of pedestrian deaths
Cars and light vans	113
Heavy goods vehicles	16
Buses and coaches	11
Motorcycles	5
TOTAL	145

Figure 4.8(i) - Pedestrian deaths according to age and sex

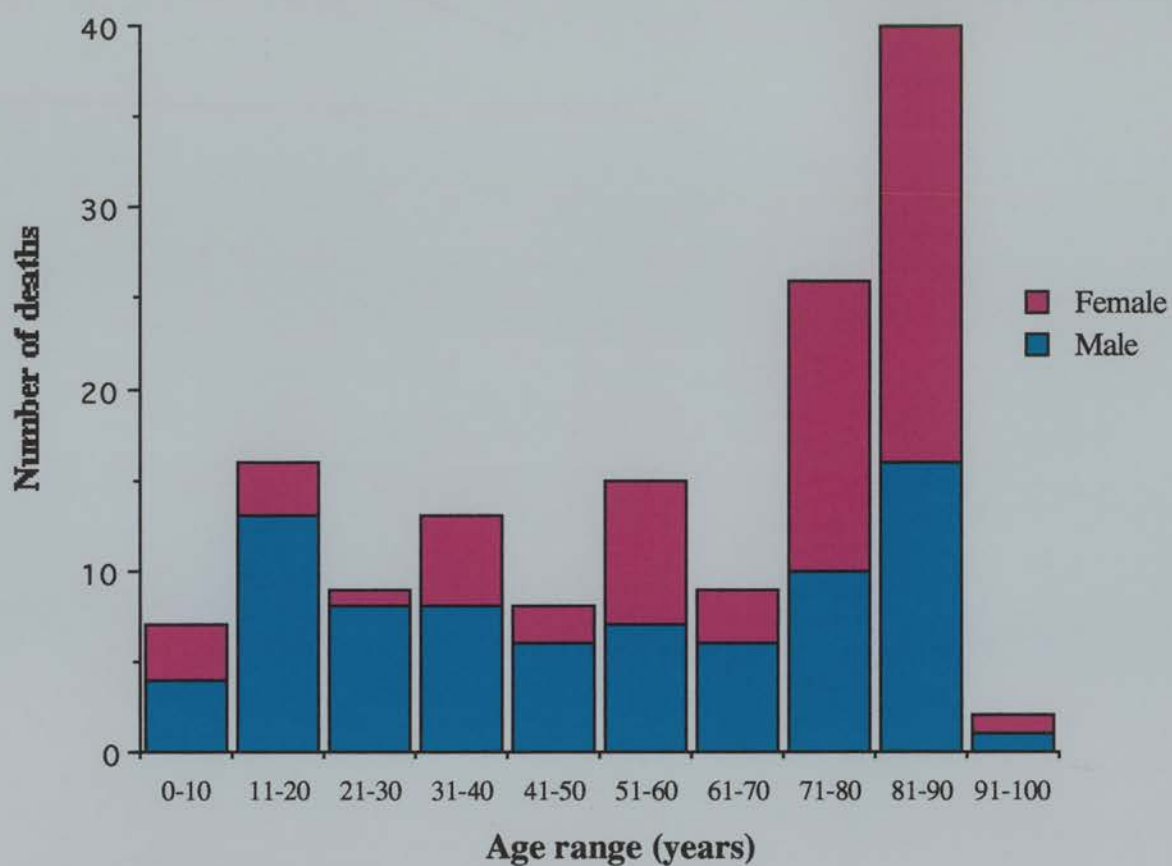


Table 4.8B - Background to the road traffic collisions resulting in pedestrian fatalities

Background to the incident	Number of deaths
Pedestrian at fault:	
Unimpaired pedestrian stepped out in front of vehicle	42
Pedestrian under influence of alcohol stepped out	10
Pedestrian under influence of drugs stepped out in front of a vehicle	1
Pedestrian physically impaired (deaf, blind, immobile) stepped out	11
Pedestrian with physical impairment & alcohol stepped out	1
Pedestrian under influence of alcohol lying or staggering in the road	17
Pedestrian tripped up in the road	5
Pedestrian illegally trying to cross dual carriageway or motorway	5
Pedestrian appeared to deliberately walk / run into path of a vehicle	6*
Pedestrian blown by the wind into the path of a vehicle	3
Foreigner crossing road looking for traffic from the left, not right	2
Other	4
Driver at fault:	
Speeding vehicle hit pedestrian crossing the road	8
Driver lost control of vehicle and mounted pavement	5
Driver's vision impaired by low sun and wet road	3
Driver ignored red light and hit pedestrian	2
Driver deliberately drove directly at a pedestrian, causing death	1†
Other	2
Both pedestrian and driver at fault:	
Driver under influence of alcohol hit drunk pedestrian	2
Speeding police car responding to "999" call hit running pedestrian	1
Pedestrian standing in gutter hit by car whilst driver changed cassette	1
No clear fault:	
Circumstances unclear	12

* These deaths appeared to be suicides

† This death appeared to be a homicide

Figure 4.8(ii) - ISS amongst pedestrian fatalities

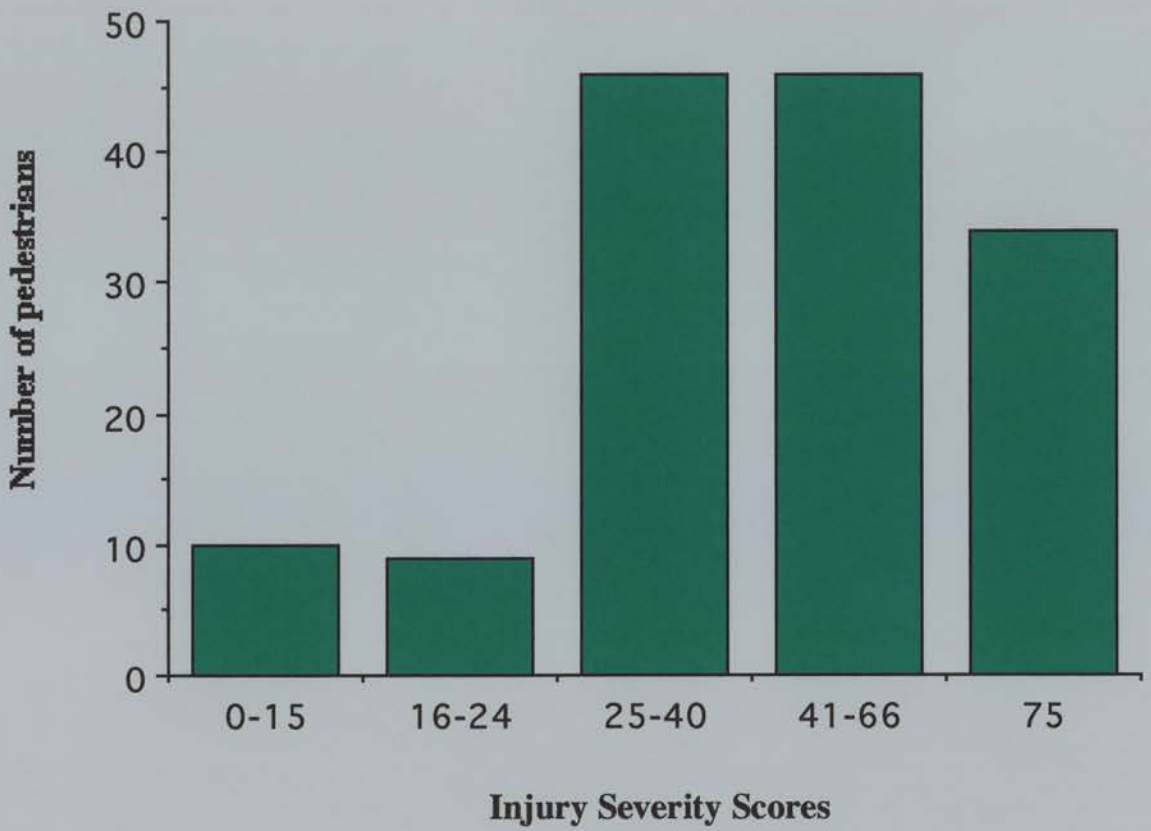


Table 4.8C - Unsurvivable pedestrian injuries (AIS = 6)

Injury	Number of pedestrians
Complete thoracic aortic injury	19
Massive cardiac injury	6
Crushed / lacerated brain & brainstem	13
High cervical spinal cord transection	9
Complete liver destruction	2

Discussion

This study confirms that fatal road traffic collisions involving pedestrians in south-east Scotland are common. Given the mis-match between the relatively frail human frame and the unyielding structure of motor vehicles, it is easy to understand how the pedestrian comes off worst in any collision, particularly when that vehicle happens to be a bus or heavy goods vehicle (Mackay, 1994). The trajectory of the pedestrian after impact with a vehicle has been characterised, demonstrating that at higher impact speeds, the pedestrian is more likely to be thrown up into the air after initial impact, sustaining secondary impacts either on the roof of the vehicle and/or onto the road surface (Harms, 1993; Mackay, 1994). The vulnerability of the pedestrian's head and neck during such a high speed impact is obvious and reflected in this and previous studies by a large number of serious and unsurvivable head injuries (Horowitz et al., 1987; Lane et al., 1994; Hill et al., 1996a). Similarly, the high proportion of unsurvivable aortic injuries in this study is consistent with very high velocity impacts (chapter 6.2; Karger et al., 2000).

Despite the unsurvivable injuries amongst some of the pedestrians, most of those who died actually survived the initial impact and reached hospital alive. This finding contrasts with the timing of death from other mechanisms of injury in both adults and children (Wyatt et al., 1995; Wyatt et al., 1997a), but is in keeping with data involving injured pedestrians in Sydney, Australia (Hill et al., 1996a). It does suggest that there may be more potential to prevent deaths by improving treatment

than with other mechanisms of injury, a suggestion borne out by the findings of a large evaluation of prehospital and hospital care (McDermott et al., 1996).

In keeping with previous studies and official figures, many of those who died were elderly and some very elderly (Copeland, 1991; Lane et al., 1994; Keall, 1995; Hill et al., 1996a; Department of the Environment, Transport and the Regions, 1998; Peng & Bongard, 1999). The effect of old age may not only have helped cause the injury (by any one or more of the following: reduced vision, deafness, slow response times, impaired judgement, confusion, poor mobility and balance problems), but also have reduced their ability to recover from injury because of pre-existing illness and reduced physiological reserve (Vestrup & Reid, 1989; Melzer et al., 1999; Peng & Bongard, 1999; Pickering et al., 1999). Observational data shows that not only do elderly pedestrians take significantly longer to cross roads, they are at greatly increased risk of being struck by a vehicle whilst doing so (Transport Road Research Laboratory, 1980; Keall, 1995). Having been hit, unsurprisingly, it has been found that the very elderly have a poorer outcome following trauma (Howard et al., 1989; Sklar et al., 1989; DeMaria, 1993; Schiller et al., 1995; Shabot & Johnson, 1995; Frankenfield et al., 2000). The existence of co-morbid factors (pre-existing disease) is certainly significant in helping to determine outcome after trauma (Wardle, 1999). Similarly, there is evidence demonstrating that the metabolic response to injury amongst the elderly is quite different from that amongst the young (Frankenfield et al., 2000). Perhaps, armed with this information, those responsible for allocating resources have made “difficult choices” and been reluctant to extend expensive

resources to injured elderly patients. Rationing of resources according to age (“ageism”) is certainly a feature of care in many areas of medicine, yet there is evidence to suggest that elderly patients with problems as diverse as hip fractures and cardiovascular problems and various forms of trauma can do well if provided with aggressive treatment (Bowling, 1999; Jennings & de Boer, 1999). Similarly, there is evidence to support those who advocate aggressive treatment of the injured elderly (DeMaria, 1987; Scalea et al., 1990; Broos et al., 1993; Zietlow et al., 1994). It may be that, unlike other forms of trauma, here lies some realistically significant potential to reduce the trauma death rate by improving hospital treatment.

Pedestrians were implicated as causing most collisions, a finding in keeping with previous data (Teanby et al., 1993). Many were elderly and/or under the influence of alcohol/drugs and evidence suggests that it may be difficult to change behaviour of these groups (Jonah & Engel, 1993; Hoxie & Rubenstein, 1994). Injury prevention measures may be most effectively targeted towards altering drivers’ behaviour and towards making motor vehicles more pedestrian friendly in the event of a collision (Harms, 1993; Mackay, 1994).

4.9 Conclusions

Analysis of trauma deaths according to mechanisms of injury and with regard to whether or not the injuries occurred intentionally has yielded useful insights. It certainly appears that different mechanisms of injury are associated with very different background causes, produce different patterns of injury and timing of death. Therefore, each mechanism of injury deserves separate consideration. There certainly appear to be some common themes in terms of causation, particularly as far as the role of alcohol is concerned - this is studied in greater detail in chapter 7.

Differences exist between mechanisms of injury in the extent to which improved prehospital care might reduce the trauma death rate. The results outlined earlier in this chapter indicate that there appears to be particular potential to save lives from drowning by improving prehospital care. The role of prehospital care is considered further in chapter 8.

The data in chapter 3 suggest that since the majority of individuals who die after trauma do not survive long enough to reach hospital alive, there is greatest potential to “save lives” from trauma by injury prevention and/or prehospital interventions. However, historically there has been (and there continues to be) enormous interest in trying to improve hospital care of victims of all forms of trauma, with a view to reducing the death rate. This interest is entirely understandable and justifiable. Analysis of data presented in this study suggests some areas where improved hospital treatment may make an impact on the trauma

death rate. Most prominent in terms of mechanisms of injury is death amongst pedestrians involved in road traffic collisions, since the majority of pedestrians who died actually reached hospital alive. Further consideration into the potential role of improved hospital care in reducing the trauma death rate is given in chapter 9.

Chapter 5 - Analysis of paediatric deaths according to mechanism of injury

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5.2	Child road traffic collision deaths	page 228
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5.1 Death from hanging in children

Background

Death from hanging amongst adults is recognised to be a common occurrence in many parts of the world (Pounder, 1993; Cooke et al., 1995; Office for National Statistics, 1997). In contrast, death from hanging in children appears to be uncommon, although the exact epidemiology of this occurrence is relatively unknown. This is reflected in the literature: much of the published work has taken the form of one or two case reports, rather than large series of cases (Robertson et al., 1981; Perrot et al., 1985; Busuttill & Obanfunwa, 1993; Hord & Anglin, 1993; Little, 1994; Byard et al., 1996; Petruk et al., 1996). Examination of the cases of a complete series of children who die following hanging is required in order to allow an insight into how these deaths might be prevented.

Methodology

Deaths due to hanging in children aged less than 15 years in the Lothian and Borders regions of south-east Scotland during 1985–1996 were identified from records of the Forensic Medicine Unit and Procurator Fiscal. The dataset was confirmed to be complete by checking the records of all children who died following trauma during these 12 years and by checking against data held by the Registrar

General. The circumstances surrounding the deaths, the treatment provided and the findings at autopsy and after toxicological analysis were obtained from a variety of sources, including the records of the Forensic Medicine Unit, Procurator Fiscal, police, ambulance and hospital (see chapter 2).

Results

Rate of paediatric hanging deaths

143 children died after trauma during the 12 years: eight deaths appeared to be suicides, the remaining 135 accidents or homicides. The mechanisms of injury responsible for the 143 deaths following trauma are shown in table 5.1A. Twelve patients died from hanging comprising ten boys and two girls, aged between four and 14 years. Given that the 1991 Census recorded 146,826 children aged less than 15 years to be living in Lothian and Borders regions, the rate of death from hanging in south-east Scotland was calculated to be 0.7 deaths per 100,000 children per year (Office of Population Censuses and Surveys, 1993). Details of the 12 cases are shown in table 5.1B.

Medical treatment

Ten of the hangings were unwitnessed. The two incidents which were witnessed were observed by children, not adults. In all cases, by the time that help arrived the child was in cardiac arrest. Only one child was initially resuscitated

successfully such that there was a period of return of spontaneous circulation - this child was admitted to hospital where she died 12 hours later.

Suicidal hangings

Six deaths exhibited suicidal intent and the remaining six appeared to be unintentional. The six children who appeared to have deliberately killed themselves were aged between 11 and 14 years. Three children wrote a suicide note or expressed a suicidal intention to a friend and although there was no direct evidence that this precipitated the suicide, three were in trouble with police or school authorities about possession of illegal drugs. Only one of the deaths was to any extent predictable - one child had an unaddressed psychological problem (related to the fact that he had been deeply disturbed by the sudden traumatic death of a friend two years previously) and had repeatedly stated his suicidal intent. Four of these six children were found hanging completely suspended, with no contact with the ground; the other two were incompletely suspended with their feet in contact with the ground.

Accidental hangings

The six children who died from hanging as a result of accidents were aged between four and 14 years. Two were found hanging completely suspended, the remaining four were incompletely suspended. Five of the six children appeared to have been engaged in experimental behaviour involving ligatures around their necks which had gone tragically wrong. One child accidentally hung herself whilst playing

unsupervised with a dog's lead on a garden playslide. The circumstances surrounding the six unintentional deaths were examined to ascertain whether they were preventable. The death of one child (the unsupervised four year old girl) would almost certainly have been prevented if her play had been supervised.

Autopsy findings

At autopsy, none of the 12 children had cervical spine, hyoid or thyroid fractures. Petechial haemorrhages were observed on the face and neck above the ligature mark in five children: all had been found hanging incompletely suspended. Blood was taken from all except the youngest three children for toxicological analysis: no trace of alcohol or common drugs of abuse / solvents were detected within the blood of the nine children tested.

**Table 5.1A - Causes of paediatric deaths from injury in south-east
Scotland 1985–1996**

Mechanism of injury	Number of deaths (%)
Road traffic collisions	68 (48%)
Fire	22 (15%)
Drowning	17 (12%)
Hanging	12 (8%)
Falls	12 (8%)
Other	12 (8%)
TOTAL	143 (100%)

Table 5.1B - details of the hangings

No.	Age (years)	Sex	A/S	P/C	Ligature	Location
1	4	F	A	P	Dog's lead	Home (garden)
2	6	M	A	P	Dressing gown cord	Home
3	10	M	A	P	Dressing gown cord	Home
4	11	F	A	P	Indoor clothes line	Home
5	11	M	S	C	Rope	Tree
6	11	M	A	C	Rope	Home
7	12	M	S	P	Electric cable	Home
8	12	M	S	C	Rope	Tree
9	13	M	S	C	Suitcase webbing	Home
10	14	M	S	P	Belt	Home
11	14	M	A	C	Rope	Tree
12	14	M	S	C	Long sock	Home

A/S "accident" / suicide

P/C partial / complete suspension

Discussion

This study shows the rate of death from hanging amongst children within south-east Scotland to be 0.7 deaths per 100,000 children per year. Although this is a much lower rate than that amongst British adults (Pounder, 1993), hanging accounted for as many deaths as did falls from heights amongst children in south-east Scotland, during the 12 year study period. In its position as the fourth most common mechanism of traumatic death amongst children, hanging remains neglected from a prevention perspective.

Ten of the 12 children in this study who died from hanging were boys. This male predominance is in keeping with that seen amongst children dying following trauma from all causes (Registrar General for Scotland, 1996). It is also consistent with the sex ratio seen amongst adults who die following hanging in Scotland (Registrar General for Scotland, 1996) and in other countries (Pounder, 1993; Cooke et al., 1995).

Six (50%) of the children in this series were found hanging completely suspended, contrasting with the low rate of complete suspension seen in adult hangings. This difference may reflect both children's perspective on how to commit suicide by hanging and the low rate of unintentional hangings in adults, when compared with children (Pounder, 1993; Cooke et al., 1995). The high rate of complete suspension leading to rapid death in children is responsible for the lack of petechial haemorrhages found at autopsy (Luke et al., 1985). Autopsy examination revealed that none of the 12 children had hyoid or thyroid fractures. This contrasts

with the findings in adult hangings, where the reported incidence is as high as 67% (Betz & Eisenmenger, 1996). Neither alcohol nor drugs of abuse were detected in any of the children at autopsy, despite the fact that the suicides of three of the children were possibly precipitated by the trouble that they were in because of possession of illegal drugs.

Most of the deaths occurred in and around the home environment, and none were witnessed by adults. Indeed, by the time the children were found, none showed any sign of life. In some, the child had clearly been hanging for a period of hours before being found. As a consequence, only one child was resuscitated successfully initially, and that child died later in hospital. Survival after hanging injury ("near-hanging") in childhood appears to be uncommon - in two recent reports involving five cases, children were found unconscious and were not breathing, but they were not pulseless (Digeronimo & Mayes, 1994; Howell & Guly, 1996). This is consistent with the universally recognised poor outcome of attempted resuscitation of children in cardiac arrest (Nadkarni et al., 1997). When these factors are considered together with the lack of adult presence at the time of the hanging, it is apparent that there is little potential to reduce the death rate by improving the treatment for those children found already hanging. Instead, the focus needs to be placed upon attempting to prevent the hanging occurring in the first place.

Although not a feature of this series, previous reports demonstrate the hazards of certain sleeping environments to infants and young children (Sturner et al., 1976; Feldman & Simms, 1980; Cooke et al., 1989; Clark et al., 1993; Moore &

Byard, 1993; Byard et al., 1994; Cooke et al., 1995; Byard et al., 1996). Such deaths are eminently preventable through a combination of adequate parental supervision and statutorily imposed constraints on manufacture of cots, beds and stroller prams. Similarly, deaths of some younger children during play might be prevented by restricting them access to ligatures.

However, it is neither reasonable nor practicable to suggest that children can be denied access to all potential ligatures, particularly given that the ligatures in this series were items of the type likely to be found in all households and often used in play activities. The emphasis shifts to educating children about the dangers of playing with ligatures and when appropriate, to ensure that adequate supervision is available. However, one unintended consequence of highlighting the risks of potential ligatures is that by increasing the focus on hanging, the interest of children in hanging might perversely be also increased. This seems particularly likely amongst the teenage age group and necessitates a carefully balanced assessment, bearing in mind that the risk of death by hanging to any one individual child is relatively low.

Unintentional death from hanging during auto-erotic behaviour with a definite sexual component has been described in children aged nine years and over (Feldman & Simms, 1980; Cooke et al., 1995; Nixon et al., 1995; Uva, 1995), but appears to be very uncommon. No cases unequivocally of an auto-erotic nature were observed in this series. Frequently, this behaviour may only come to light for the first time after a tragic event, rendering prevention impossible.

The current series contains a high proportion (50%) of apparent suicides. The three previous series of paediatric hanging deaths describe a total of 30 cases, of which only three (10%) were described as suicides, five as equivocal or possible suicides (17%), two as homicides (7%), and 20 as "accidents" (67%) (Cooke et al., 1989; Clark et al., 1993; Cooke et al., 1995). The six suicides in the children (aged between 11 and 14 years) in this series are of considerable concern. This concern mirrors that regarding the recent rise in the suicide rate amongst children in the USA (Centers for Disease Control and Prevention, 1997; Lee et al., 1999). However, equivalent figures for England and Wales do not show any similar recent increase (McClure, 1994). The same would seem to be true of Australia, where suicide rates amongst children do not appear to have altered significantly during the past century (Byard et al., 2000b).

The first obvious step in attempting to prevent suicide in children is to identify those children at risk (Williams, 1997). Of the six suicides in this study, only one had voiced previous suicidal ideation: this child appeared to have unaddressed psychological problems. The remaining five children appeared to have committed suicide impulsively during what responsible adults might consider relatively minor stressors: the extent to which these children were experiencing other non-disclosed difficulties is, of course, unknown. One possible non-disclosed difficulty is bullying at school. This has recently been acknowledged to be a relatively common problem amongst adolescents in different parts of the world and is believed to be associated with suicidal ideation (Chesson et al., 1999; Forero et al., 1999; Kaltiala-Heino et al.,

1999). Recognition of this has resulted in media attention and the introduction of measures designed to identify and help those affected (Hopkins, 1999).

Combining this series with previous reports allows a broad classification of paediatric hanging deaths according to age and circumstances (table 5.1C). Although the way forward in terms of preventing all of these deaths is not clear, there appears to be potential for some deaths to be prevented through a combination of manufacturing legislation, increased parental supervision, education and restricting young children access to ligatures.

Table 5.1C - Broad classification of paediatric hanging deaths

Age of child (typical age affected)	Circumstances of hanging
Infants and young children (0–2 years)	Trapped by ligature in sleeping environment (e.g. cot, bed, pram)
Young children (2–8 years)	Caught incidentally during play by a ligature
Older children (≥ 8 years)	Play focused on ligatures or acting out a pretend “hanging”
Older children (≥ 11 years)	Suicide
Older children (≥ 13 years)	Auto-erotic sexual behaviour
All ages	Homicide, often associated with sexual assault

5.2 Child road traffic collision deaths

Background

It is well recognised that injury is a leading cause of death in children (Committee on Trauma Research 1985; Registrar General for Scotland 1996). The Government has recognised the pre-eminent role of trauma and set targets for a reduction in the death rate (Health of the Nation 1992). In addition to the death toll, there is an enormous amount of long-term disability and morbidity amongst seriously injured children (Jarvis 1995; Registrar General for Scotland 1996; Walsh 1996). Road traffic collisions (colloquially known as “road accidents”) account for the greatest proportion of the total of both deaths and serious injuries in children (Registrar General 1996; Wyatt 1997a). Therefore, in order to achieve the government’s target and reduce the death rate from trauma in children, attention needs to be focused upon road traffic collisions.

Prevention of serious injuries and traumatic deaths has been usefully categorised as follows (Nicholl, 1999):

- **Primary prevention** - the prevention of events (whether deliberate or unintentional) which result in injury (e.g. measures effective in reducing the speed of motor vehicles in a built-up area, so that road traffic collisions do not occur).

- **Secondary prevention** - the reduction of the severity of injuries following trauma, or the successful prevention of injuries occurring at all (e.g. the use of vehicle seat restraints).
- **Tertiary prevention** - the prevention of deaths or long-term morbidity by the provision of more timely and appropriate treatment of those injured.

The aim of this study was to examine the circumstances surrounding the deaths of children in road traffic collisions in south-east Scotland, in order to try to identify where potential exists to reduce the death rate.

Methods

All deaths amongst children aged less than 15 years in Lothian and Borders regions of south-east Scotland which were the result of road traffic collisions between 1985 and 1998 (inclusive) were identified from the records of the Registrar General (chapter 2.4) A cross-check was performed against the data held by local hospitals and the Procurator Fiscal.

Each traumatic death involving a child in south-east Scotland is investigated by the police upon the instructions of the Procurator Fiscal and a detailed report regarding the circumstances of each fatal collision is prepared (chapter 2.3) based upon eye witnesses, hospital records and the results of police road accident investigation (both of the scene and any vehicles involved). In addition, the bodies of

all children who die following trauma in south-east Scotland undergo detailed examination at autopsy by the Forensic Medicine Unit of the University of Edinburgh on the instructions of the Procurator Fiscal (chapter 2.8). This study used the information contained within the police reports and the autopsy reports, together with details of any prehospital and hospital treatment provided, which was obtained from ambulance and hospital records (chapter 2.5).

Details of injuries sustained were extracted from hospital records and the detailed autopsy reports. All injuries were scored according to the AIS (1990 revision), yielding both the MAIS and ISS for each death (Baker et al., 1974; AAAM, 1990; chapter 2.7). The patterns and severity of injury was compared with mechanism of injury according to whether the child was a pedestrian struck by a vehicle, an occupant in a vehicle or a bicyclist involved in a collision.

Results

Basic epidemiology

During the 14 year study period there were 179 deaths amongst children as a result of all forms of trauma (excluding poisonings) in south-east Scotland. 89 of these children (53 boys, 36 girls) died after road traffic collisions. Given the 1991 Census known resident population of children aged less than 15 years in south-east Scotland of 146,826, the average death rate amongst children from road traffic collisions in the region was 4.3 per 100,000 children per year, a figure not dissimilar

to the national Scottish average of 4.2 per 100,000 children per year in 1991, the mid-point of the study (Office of Population Censuses and Surveys, 1993; Scottish Office 1994). The road traffic collision death rate amongst children in south-east Scotland varied considerably from year to year (ranging from 2.0 in 1992 and 1996 to 8.9 per 100,000 children per year in 1991), with no discernible temporal trend.

The 89 children who died following road traffic collisions comprised: 44 pedestrians (49%), 33 passengers in cars (37%), and 12 pedal cyclists (14%). The mean ages of the children who died in each of these groups were as follows: pedestrians - 9.2 years; car passengers - 6.5 years; cyclists - 10.9 years.

Circumstances relating to the road traffic collisions

The 44 pedestrians who died were aged between two and 15 years. The 44 deaths followed 39 separate incidents. The circumstances of the child pedestrian deaths are shown in table 5.2A. Eight of the pedestrians were aged less than five years, of whom four were unsupervised at the time of the collision.

33 children (with ages ranging from 4 months to 15 years) died whilst passengers in cars which were involved in a total of 27 separate incidents. The deaths of 24 children resulted from "aberrant" actions of the car drivers carrying the child. The deaths of seven children resulted from actions of the drivers of the other cars. Analysis of the circumstances regarding the deaths of two children failed to reveal exactly what happened and who or what was "responsible" for causing the collision.

Eighteen of the children who died in cars were not restrained at the time of the collision.

Twelve cyclists (with ages ranging between five and 15 years) died in twelve separate incidents. In eleven cases, the child was considered solely responsible for causing the collision. In the remaining one case, the child cyclist swerved suddenly into the path of a car in order to try to avoid a "pothole" defect in the road surface (table 5.2B).

Timing of death

Fifty-nine of the 89 children (66%) died following the road traffic collisions before reaching hospital. Fifty-one of these 59 children (57% of the total number of paediatric road traffic collision deaths) either died instantly or were dead when found at the scene of the incident.

Analysis of injuries

All 89 children who died had ISS of more than 15. The range of ISS is shown in figure 5.2(i). Three cases could not be scored due to the fact that mechanism was not scorable according to the AIS - these cases comprised two crushed pedestrians who died as a result of asphyxia following a crush injury and one car passenger who drowned when the car driver lost control and the car went into a river).

Twenty-three children died with injuries which are acknowledged to be unsurvivable (AIS = 6, ISS = 75). The unsurvivable injuries sustained are listed in

table 5.2C. Analysis of each individual child's injuries yielded Maximum AIS (MAIS). The AIS body regions which were responsible for the MAIS according to mechanism of injury is shown in figure 5.2(ii).

Table 5.2A - Circumstances of the 44 child pedestrian deaths

Behaviour	Number of children
Error crossing the road / ran into road unexpectedly	25
Trying to cross where pedestrians are prohibited	8
Playing in the road	3
Car driver at fault	2
Ran away from danger into road	1
Walked into road under influence of alcohol	1
Circumstances unclear	4

Table 5.2B - Circumstances of the 12 fatal cyclist collisions

Behaviour causing cycle accidents	Number of deaths
Swerved unexpectedly into path of another vehicle	6
Attempting a sudden manoeuvre without warning	3
Cycled directly into a reversing vehicle	1
Swerved into path of another vehicle to avoid pothole	1
Fell from bicycle into path of another vehicle	1

Figure 5.2(i) - ISS of child road traffic deaths

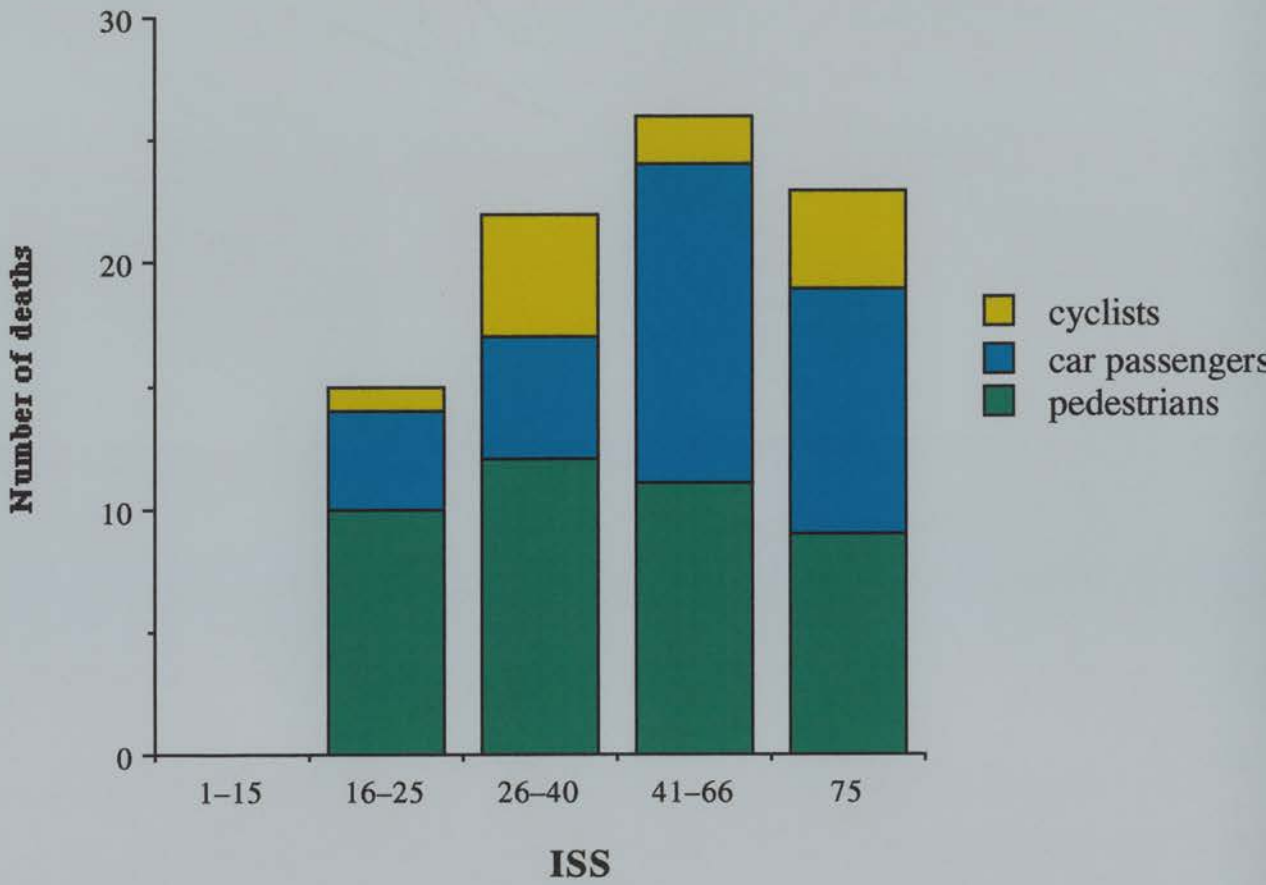


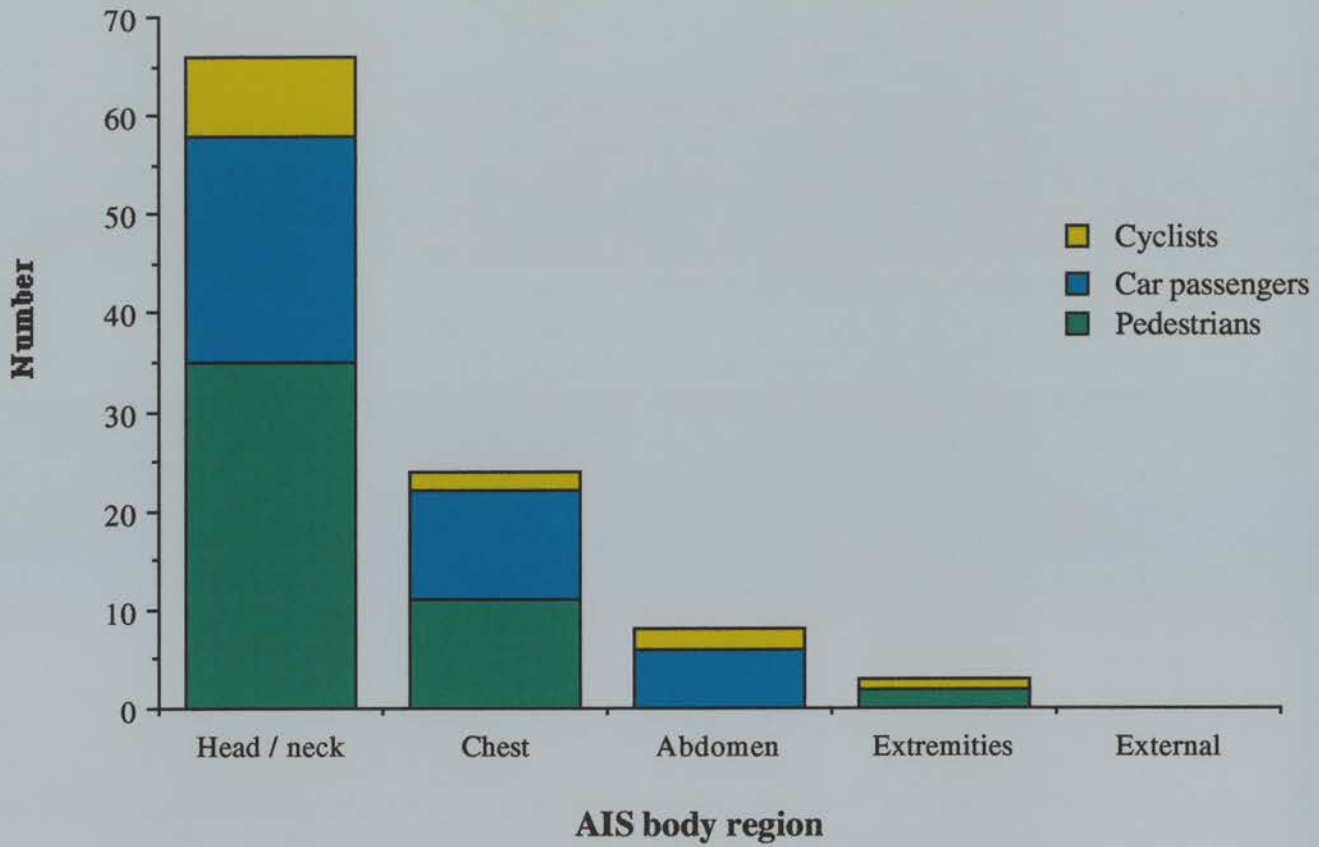
Table 5.2C - Unsurvivable injuries sustained by the child road traffic collision deaths

Injury	Number of patients
Brain / brainstem injury	12 #
High cervical spine transection	7
Thoracic aorta rupture with exsanguination	4 *
Massive cardiac disruption	2 *#
Massive liver destruction	1 #

* one patient had unsurvivable injuries of both heart and thoracic aorta

one patient had unsurvivable injuries involving brain, heart and liver

Figure 5.2(ii) - MAIS of child road traffic deaths



Discussion

Encouragingly, data show a downward trend in the number of child road traffic deaths in the UK in recent years (Department of Transport and the Regions, 1998). However, as in previous studies in other regions, road traffic collisions account for approximately half of all deaths following trauma in children (Keeling et al., 1985). The numbers in this study do not allow meaningful conclusions to be drawn about long-term trends, but in keeping with other parts of the UK, road traffic collisions exact a terrible toll on the children in south-east Scotland. The distribution of child road traffic deaths in south-east Scotland, in terms of both numbers and average ages, between pedestrians, car passengers and cyclists, mirrors national figures (Department of Transport and the Regions, 1998). It is largely a reflection of the amount of time spent by children on the roads at various ages, so for example, the average age of the cyclists is higher than pedestrians or car passengers, reflecting the older age at which child cyclists tend to appear on the roads.

It is notable that two-thirds of the fatally injured children failed to reach hospital alive. This does not appear to be the result of inadequate prehospital care, since most of the prehospital deaths occurred immediately or very rapidly indeed, such that the children were dead when first found. Part of the explanation for this is that a significant proportion had unsurvivable injuries, particularly involving the head and/or neck. Given this data, it appears that there is less potential to reduce the death rate by improving prehospital and hospital care ("tertiary prevention"), compared with other forms of injury prevention ("primary and secondary prevention").

There is evidence to suggest that in the past there were some deficiencies in the management of injured children in the UK (Sharples et al., 1990). In a more recent study, it was suggested that improvements in hospital care between 1989 and 1995 were at least partly responsible for the recent decline in trauma death rate in children in the UK (Roberts et al., 1996), although as far as road traffic deaths were concerned, some of the recent decline appears to have resulted from significant changes in child travel patterns (less walking and cycling) (DiGuseppi et al., 1997). Analysis of the quality of care using the standard TRISS methodology in routine world-wide use in the study of adult populations (Boyd et al., 1987) has been claimed to be reliable in predicting survival probabilities in children (Eichelberger et al., 1993). However, TRISS methodology is generally acknowledged to be more problematic in children, since both the Abbreviated Injury Scale and Revised Trauma Score upon which the system is based were produced with adults, not children in mind (Baker et al., 1974; Beattie et al., 1998; AAAM, 1990; chapter 2.7). Also, considering the relatively small number of seriously injured children surviving to reach hospital when compared with adults, it is difficult to apply TRISS methodology in children and draw meaningful conclusions. Certainly, in this study all those children who died had ISS of greater than 15 (implying at least moderately severe injury), and many had injuries acknowledged to be unsurvivable. This data, when combined with that relating to the timing of death, reinforces the importance of primary and secondary prevention as the way forward.

Analysis of the circumstances of the fatal road traffic collisions revealed a predictably common theme as far as causation was concerned - human error. Primary prevention of these fatal injuries therefore needs to target the behaviour of road users. Although child road users (in the form of pedestrians and cyclists) were heavily implicated in having undertaken actions which directly contributed to their own fatal road traffic collisions, the responsibility of adults in helping children to safely use the roads must be acknowledged. Work relating to child pedestrians demonstrates that children aged less than ten years have difficulties with various aspects of safely crossing the road, including: identifying safe crossing points and making safe judgements about time and space (gaps in the traffic) (Thomson et al., 1996). Similar reservations about the motor skills and judgement of younger child cyclists has resulted in justifiable concern about their ability to safely mix with other traffic (Simpson & Mineiro, 1992).

The pre-eminence of head / neck injury in being responsible for MAIS and causing death is apparent in all three categories of child road traffic deaths and has been observed in studies from other parts of the world (Adesunkanmi et al, 2000). The secondary prevention of serious head injuries is therefore an important aim in all three categories, although success may require a different approach in each case. For cyclists, helmets offer obvious, direct protection, whereas car passengers receive indirect protection from seat restraints. There is substantial evidence to support the use of cycle helmets (Maimaris et al., 1994; Pitt et al., 1994; Thomas et al., 1994), but it has not proved easy to persuade the UK public to adopt them (Maimaris et al.,

1994). Similarly, there is a large amount of evidence dating back over several decades which supports the use of car seat restraints (Trinca & Dooley, 1975; McDermott & Hough 1979; Bodiwala et al., 1989; Richmond et al., 1989) and yet, despite legislation, it has been difficult to persuade the UK public to use them, particularly rear seat belts (Wyatt & Richardson, 1994). Protecting child pedestrians in the event of a collision with a vehicle requires consideration to be given to the design of the front of vehicles to make them more pedestrian-friendly. Experimental work suggests that this would be achievable, but at the expense of the vehicle's appearance and cost, which in modern society remain considerable barriers to progress (Harms, 1993; Mackay, 1994).

5.3 Conclusions

The death of any person after trauma is upsetting, and invariably evokes feelings of "wasted years" and lost potential of life. For young people and children, untimely deaths from trauma clearly exact a large toll in terms of lost years of life. The vulnerability and innocence of children renders the topic of deaths following trauma in such an age group even more emotive. Considering this, the relatively low rate of paediatric trauma deaths in south-east Scotland is pleasing but of no cause for complacency or celebration. The data presented in this chapter and also in chapter 3.2 do suggest that improvements in hospital care would not impact dramatically on the overall paediatric trauma death rate. This observation appears to hold true for the two mechanisms of injury which were studied in this chapter (5.1 and 5.2), which included the mechanism of injury responsible for the greatest proportion of deaths: road traffic collisions.

Analysis of the circumstances surrounding the deaths of children from hanging (Wyatt et al., 1998b) and from road traffic collisions revealed that in the majority of cases, it was the intrinsic actions of the children themselves which led in a more or less direct and often rather predictable fashion to their sustaining fatal injuries. Despite this finding, it is neither acceptable nor reasonable simply to apply "blame" to children in this setting and leave the matter at that. In the cases of younger children (particularly of pre-school age), the role of parents, carers or guardians in ensuring a safe environment and adequate supervision is obviously very important.

The aims of altering the behaviour of children to render them less at risk in potentially dangerous situations and of reducing the amount of contact children have with potential dangers are both worth pursuing and may offer some potential for a decrease in morbidity and mortality. However, it is also necessary to recognise that despite every effort, children will inevitably continue to come into contact with potential dangers on a fairly regular basis. There needs to be a change in the attitude amongst every group in society such that it becomes a collective responsibility to protect children. Only then, for example, will the average motor car driver, travelling (just) within the legal speed limit in a residential area, take some responsibility for the safety of a child he/she observes on the pavement and slow down in acknowledgement of the fact that there is a possibility that they might suddenly run out into the road.

Chapter 6 - Analysis according to pathological injury

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6.1 Rationale for considering injuries according to pathological injury

The researcher investigating how deaths following injury may be prevented may adopt a number of approaches. One is to analyse deaths according to various mechanisms of injury (e.g. falls, road traffic collisions) each of which may be subdivided further (e.g. high falls / low falls / falls down stairs; road traffic collisions involving: pedestrians / motorcyclists / vehicle drivers and passengers). Analyses of deaths from these various mechanisms of injury may yield information about how the injuries may have been prevented and/or how they may have been better treated. This approach has been followed in chapters 4 and 5.

An alternative approach is to analyse deaths according to the pathological injuries sustained. The focus will naturally fall upon those pathological injuries associated with a high mortality. Having identified such injuries, an investigation of the underlying pathophysiological mechanisms may allow an insight into what measures might prevent the injuries. Additionally, an analysis of the treatment given to those individuals who succumbed to certain specific pathological injuries may enable a judgement to be made as to whether potential exists to improve diagnosis and treatment of these injuries. Such an analysis will be more powerful if it includes not only those individuals who died from a particular injury, but also those who survived following treatment. This is the approach adopted in this chapter.

6.2 Thoracic aortic injuries in south-east Scotland

Background

Of all the many injuries to various organs in the body which have been described, injury to the aorta has long been recognised to be potentially catastrophic (Kemp, 1923; Strassmann, 1947; Parmley et al., 1958; Passaro & Pace, 1959; Beall, 1960; von Oppell et al., 1994). Previous reports have either concentrated upon hospital presentation, investigation and management of patients with aortic trauma (Keen, 1972; Turney et al., 1976; Ayella et al., 1977; Pickard et al., 1977; Akins et al., 1981; Kram et al., 1989; Clark et al., 1990; Cowley et al., 1990; Delrossi et al., 1990) or upon autopsy findings (Sevitt, 1977a; Feczko et al., 1992). This study provides the first complete prospective epidemiological picture of all thoracic aortic injuries in a defined population in the UK.

Methods

STAG and University of Edinburgh Forensic Medicine Unit prospectively collected data on all serious injuries and deaths from trauma in Lothian and the Borders regions of South-East Scotland over two years (February 1992 - January 1994). The methodology of trauma data collection has previously been reported (Wyatt et al., 1995). The data collected included age, sex, mechanism of trauma,

details of the injuries sustained, investigations, treatment and outcome. On the instructions of the Procurator Fiscal, all traumatic deaths for the entire geographical area are autopsied by the same team according to a standardised comprehensive protocol. All injuries were recorded and scored according to the AIS 1990 revision, allowing ISS to be calculated (AAAM, 1990).

Results

Incidence

There were 52 thoracic aortic injuries amongst the 0.83 million population of Lothian and Borders in the two year study period. The 52 patients comprised 38 males and 14 females, age range of 16 - 84 years, mean 40 years (table 6.2A).

Mechanism of injury

49 aortic injuries followed blunt trauma and three followed penetrating knife injuries. The mechanisms of the 52 injuries are shown in table 6.2B. Nine aortic injuries were sustained in suicide attempts (falls), three were homicides (stabbings) and the remaining 40 resulted from "accidents".

Severity of the aortic injuries

The injuries were subdivided into intimal tears, partial ruptures and complete transections and were scored according to the AIS (table 6.2C). Thirty-six patients

sustained complete transections, 35 of which were complete transections with massive haemorrhage not confined to the mediastinum. Eight patients had complete transections at multiple sites, 28 had single complete transections. Twenty (71%) of these 28 single complete transections occurred at the level of the junction of the junction of the arch and descending aorta, just distal to the ligamentum arteriosum.

Other injuries

Forty-seven patients (90%) had injuries involving other body systems. The most common associated injury was rib fracture. Sixteen patients (31%) had non-aortic injuries recognised to be incompatible with survival (AIS = 6, ISS = 75). Injury Severity Scores ranged from 16 - 75 (table 6.2D).

Outcome

Twelve of the 52 patients (23%) with aortic injuries reached hospital: three of these were in cardio-respiratory arrest on presentation to hospital. Two patients survived to hospital discharge (table 6.2E). In the two year study period there were a total of 349 deaths following trauma in Lothian and the Borders. Therefore, 14.3% of all those who died from trauma had sustained an aortic injury.

Table 6.2A - Age and sex of 52 patients with aortic injuries

Age (years)	Male	Female	Total
0 - 10	0	0	0
11 - 20	7	4	11
21 - 30	8	1	9
31 - 40	8	5	13
41 - 50	5	0	5
51 - 60	2	1	3
61 - 70	1	1	2
71 - 80	6	1	7
> 80	1	1	2
Total	38	14	52

Table 6.2B - Mechanism of aortic injury

Mechanism	Number	%
Road traffic collision - car occupant	21	40
Road traffic collision - motorcyclist	3	6
Road traffic collision - pedestrian	13	25
Falls (all more than 2m)	9	17
Industrial accidents	3	6
Stabbings	3	6
TOTAL	52	100

Table 6.2C - Aortic injuries scored according to the Abbreviated Injury Scale

Abbreviated Injury Scale (AIS)	Number	%
AIS 4	9	17
AIS 5	8	16
AIS 6	35	67

Notes:

AIS 4 - includes intimal tears and incomplete transections with blood loss $\leq 20\%$ by volume.

AIS 5 - includes partial and complete transections where haemorrhage is confined to the mediastinum.

AIS 6 - includes complete transections where haemorrhage of $>20\%$ by volume is not confined to the mediastinum.

Table 6.2D - Injury Severity Scores

ISS	Number	%
0 -15	0	0
16 - 24	2	4
25 - 35	3	6
36 - 74	9	17
75	38	73

Table 6.2E - Outcome after aortic injury

Outcome	Number	%
Died at scene or during hospital transfer	40	77
Died in A&E	3	6
Died in theatre	7	13
Survived following surgery to discharge	2	4

Discussion

This study has defined the incidence of thoracic aortic injuries in the Lothian and Borders regions of South-East Scotland as 1 per 32,000 people per year. The annual death rate is 1 per 33,200 people.

The great majority of thoracic aortic injuries followed blunt injury rather than penetrating injury. The small number of penetrating aortic injuries is a reflection of the combination of the relatively protected anatomical position of the aorta, together with the predominance of blunt injury over penetrating injury in the UK (Daly & Thomas, 1992; Airey & Franks, 1995; Wyatt et al., 1995; Wyatt et al., 1997a). The majority of the blunt injuries causing aortic injury occurred at the "classical site" just distal to the ligamentum arteriosum. This is in keeping both with autopsy reports and with previous studies which have focused upon those patients with aortic injuries who survived to reach hospital (Strassman, 1947; Greendyke, 1966; Turney et al., 1976; Akins et al., 1981; Hanschen et al., 1982; Clark et al., 1990).

The exact mechanism which causes aortic injury has been investigated by experiments on animals and cadavers (Lundevall, 1964; Jackson et al., 1968; Coermann et al., 1972). It was previously considered that differential rates of deceleration between the aortic arch and the descending aorta resulted in the commonly observed shearing transverse rupture at the junction between the two (Keen, 1972; Sevitt, 1977b). This mechanism, however, does not properly explain rupture of the thoracic aorta after crush injury, which accounted for three cases in this series and has been reported elsewhere (Reid et al., 1999a). Alternative

mechanisms have recently been suggested. These include the “osseous pinch mechanism”, in which the left clavicle, first rib and sternum act together to “pinch” the aorta against the thoracic spine as they are forced posteriorly and inferiorly (Crass et al., 1990; Cohen et al., 1992; Shkrum et al., 1999). Whichever mechanism is responsible, it is clear that aortic injuries usually result from the application of very large forces: most injuries followed high speed road traffic collisions. The fact that 67% of patients suffered complete circumferential aortic rupture with massive haemorrhage explains why the majority of the patients died at the scene. This study included all patients who sustained an aortic injury: it was not simply confined to studying those patients who reached hospital alive. As a result, the overall mortality of aortic injury was very high at 96%: this is in keeping with a recent report of blunt aortic injury from Australia (Hill et al., 1996b). This extremely high mortality is partly a reflection of the significant associated injuries in other body regions (16 patients had non-aortic injuries acknowledged to be unsurvivable). This is demonstrated in the Injury Severity Scores of the 52 patients.

It is interesting that the youngest person to sustain an aortic injury in this series was 16 years of age. This is consistent with published series, in which blunt aortic injuries in children are rarely described (Strassmann, 1947; Turney et al., 1976; Sevitt, 1977a; Akins et al., 1981; Cowley et al., 1990). The reason for this has not been established, but it may simply reflect greater elasticity of the paediatric aorta, together with a more compliant bony thorax.

Although aortic injury caused or contributed towards the deaths of 50 (14%) of the 349 patients who died following trauma in the study population, only nine patients with aortic injuries reached hospital with signs of life. Thus, the experience of any individual in managing these patients even in large centres is likely to be limited. Considering that during the study period 216 patients presented to hospital in Lothian and the Borders regions following significant trauma with an ISS of greater than 15 (Personal Communication, STAG, 1998), it is apparent that aortic injury is seen relatively infrequently by A&E staff. The low rate of hospital presentation of aortic injury, together with acknowledged difficulties in diagnosis, underlines the importance of paying particular attention to the mechanism of injury and of adopting a high index of suspicion if significant forces are involved.

There is currently much debate as to which investigations are most appropriate (CT scan, transoesophageal echocardiography or arch aortogram) (Burney et al., 1984; Bryan & Angelini, 1989; McLean et al., 1991; Durham et al., 1994; Fisher et al., 1994; Raptoulos, 1994; Johnson et al., 1995; Smith et al., 1995; Vlahakes & Warren, 1995). Similarly, there is also debate regarding treatment, with the traditional view that all patients should undergo immediate surgical repair being challenged. Some authorities advocate repair "semi-electively" after the institution of medical therapy (vasodilators, β -blockers and careful control of intravenous fluids), whilst others claim that patients with certain injuries and high risk groups, such as the elderly, may be treated with conservative therapy continued indefinitely (Wigle & Moran, 1991; Camp et al., 1994; Iannettoni et al., 1994; Pate et al., 1995). Despite

this controversy, there is general agreement that the diagnosis and extent of aortic injury should be established as quickly as possible, so that the preferred treatment can be instituted. It is therefore crucial that the definitive investigations are performed and evaluated rapidly and accurately. Patients will be best served if an established policy for urgent investigation is in place for all those with suspected aortic injury.

Despite the fact that aortic injuries present relatively infrequently to hospital, this study demonstrates that they are implicated in a significant number of deaths from trauma. The vast majority of these deaths occur at the scene of injuries. The greatest potential for reducing the number of deaths from thoracic aortic injury therefore lies with injury prevention measures. Such measures are of two basic types. Those in the first type aim to reduce the number of injurious events occurring. Examples include alterations in road layout and speed restrictions. The other type of measures are those which aim to minimise the injuries sustained in those events which do occur. Further research is required in order to establish the potential benefits of alterations in vehicle design (such as airbags in cars, position and design of seats in aircraft).

6.3 Conclusions

Pathological injuries which are associated with high rates of mortality are inevitably amongst the most difficult to treat. This appears to particularly apply to thoracic aortic injuries. The analysis of deaths following aortic injury described earlier in this chapter (Wyatt et al., 1997b) also revealed that patients with serious or unsurvivable aortic injuries often had unsurvivable injuries to other body organs and were frequently found dead at the scene of the injury. These factors emphasise the need to concentrate upon injury prevention, but at least in the case of aortic injuries, it would appear that it would be of limited value to simply target a single pathological injury.

**Chapter 7 - Scottish trauma deaths in 1995 -
implications for injury prevention**

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7.1 Accidents or injuries?

"They're funny things, Accidents. You never have them till you're having them"

(Milne, 1996)

The word "accident" is ingrained in everyday English and remains very much a word used in common parlance. The Shorter Oxford English Dictionary defines an "accident" in terms of being an "unforeseen contingency", and "that which is present by chance" (Little et al., 1980). Common use of the word "accident" implies an unpredictable event, an "act of God", something which could befall anyone. However, for many years now, many of those working in the field of death and injury prevention have questioned the use of the term "accident". They claim it to strictly be a misnomer on the grounds that most "accidents" are not unpredictable, chance events, but rather that they are occurrences which have definite causes and are highly predictable, and thus by implication, are also potentially preventable (Sternbach, 1992; Poole, 1998).

Interestingly, even the most apparently and commonly perceived extreme examples of unpredictable "accidents", lightning strikes, are actually recognised to be predictable to a certain extent, in that they tend to affect individuals standing on the highest ground, on tall buildings or under trees (Cox, 1992; Wetli, 1996). Tall buildings around the world stand witnesses to the fact that the statement "lightning

never strikes twice” is a fallacy! From the available evidence, it is possible to suggest to those most at risk, how lightning strikes may be avoided (Cox, 1992).

Those individuals working in the field of injury prevention believe that most “accidents” are preventable events, hence the emergence of the term “injury prevention” which has overtaken the older term of “accident prevention”. Table 7.1A lists a variety of phrases in everyday use in the English language which underline common attitudes to injuries and how they are caused.

For the reasons outlined above, the term “injury prevention” is preferred throughout this thesis, rather than the older term “accident prevention”. In fact, the word “accident” is becoming a bit of a "dirty" word in other professional circles. Indeed, within the current UK specialty of “Accident and Emergency Medicine” there are strong moves to drop the “Accident” part of the title, so that it simply becomes “Emergency Medicine” (Jones, 1999; Reid et al., 1999b; Rocke, 1999).

Table 7.1A - Examples of phrases in common use which demonstrate the popular attitude to "accidents"

- "it was only an accident"
- "accidents will happen"
- "it was an accident waiting to happen"
- "he was heading for an accident"
- "lightning never strikes twice"
- "I'm going to party today - I might be run over by a bus tomorrow"
- "accident-prone"
- "accident black spot"
- "road traffic accident"

7.2 Prospective study of 1305 Scottish trauma deaths in 1995

Background

An attempt to try to reduce the rate of fatal injuries following trauma amongst a certain population involves several stages. Firstly, fatalities from injury need to be identified. Secondly, the gamut of facts concerning the actual events resulting in the injuries need to be ascertained. Finally, these facts need to be looked into, carefully analysed and then actually acted upon by the introduction of preventative and prophylactic measures. The researcher working in Scotland is fortunate in that all traumatic deaths are referred to the Procurator Fiscal and are therefore relatively easily identified. Similarly, all such deaths are thoroughly investigated by a number of different agencies (see chapter 2).

Methods

All trauma deaths in Scotland during 1995 were identified prospectively by STAG and from Procurator Fiscal and General Register Office records (see chapter 2). Data was collected regarding the circumstances resulting in each death from a variety of sources, including: police, ambulance, hospital, STAG, forensic medicine, forensic laboratory and Procurator Fiscal records (chapter 2).

In Scotland, the investigation of deaths (as compared to what occurs in the rest of the UK) is private - conclusions are not marked officially in every individual case as to the mode of death, with the following exceptions:

- death caused by another person or persons where a criminal trial is held
- deaths in police custody and in prison
- deaths as a result of occupation

In the latter two instances the law in Scotland provides for the holding of a Fatal Accident Inquiry in which all the circumstances that preceded the death, including any medical treatment provided, are scrutinised in public within a court room under the direction of a Sheriff. All the evidence relevant to the death is held by the Procurator Fiscal, whose responsibility is to collect all the data concerning the death and to obtain expert advice about all the facts pertaining to it.

Results

During 1995, 1305 deaths due to trauma were identified in Scotland. Three hundred and twenty-four deaths appeared to be suicides, 105 homicides and 876 unintentional ("accidents). Alcohol was shown to be implicated as having played some role in causing 399 deaths, drugs in having caused 49 deaths and alcohol complemented by drugs in having caused an additional 18 deaths, as shown in table 7.2A. The range of blood alcohol levels of those with levels exceeding 80mg/dl (the current UK legal limit for driving) are shown in table 7.2B. The nine individuals (eight

men, one woman) with blood alcohol levels exceeding 400mg/dl had levels ranging from 417mg/dl to 463mg/dl (table 7.2C).

The extent to which alcohol was implicated in causing fatal injuries varied considerably according to the sex of those who died, with overall rates amongst men who died being 37.3%, as opposed to 16.2% amongst women (table 7.2D). Similarly, alcohol appeared to be implicated in causing fatal injuries to widely varying extents according to the mechanism of injury (table 7.2D). This table shows that alcohol was implicated particularly frequently amongst those individuals who died in fires and amongst pedestrians who died following road traffic collisions.

Analysis of the circumstances leading up to death in certain mechanisms of injury yielded useful information. The data suggested that the majority of pedestrians were “responsible” for the road traffic collisions which caused the fatal injuries, particularly when alcohol was involved (table 7.2E). In only two cases (1.6%) did the circumstances implicate an unpredictable event which might be construed as an “act of God” - in one case, the pedestrian was unexpectedly pulled by a dog on a lead, in the other, the pedestrian was blown by a sudden gust of wind (table 7.2E). Although alcohol was implicated less frequently in causing the deaths amongst vehicle drivers and passengers, analysis of the circumstances revealed that (predictable) human factors were responsible in the majority of cases (tables 7.2F and 7.2G).

Analysis of the factors involved in causing the fatal fire deaths revealed that cigarettes and alcohol, either singly or in combination, were implicated in causing a

large proportion of the fire deaths (table 7.2H). In contrast, drug use was only implicated in causing two deaths (2.4%).

Analysis of the role of alcohol in the deaths following fatal falls showed that it was involved frequently, particularly after falls down stairs (table 7.2I). Obvious exceptions to this were the 20 fatal falls which occurred during mountaineering, in which alcohol was not implicated at all. Similarly, alcohol did not appear to be involved in any way in any of the other eight mountaineers who died in mountaineering “accidents” (from asphyxia due to avalanches).

Table 7.2A - Role of alcohol and/or drugs in causing trauma deaths

Contributory factor	Male	Female	Total
Alcohol	346	53	399 (31%)
Alcohol and drugs	18	0	18 (1%)
Drugs	36	13	49 (4%)
Neither alcohol nor drugs	577	262	839 (64%)
TOTAL	977	328	1305

Table 7.2.B - Range of blood alcohol levels in those with blood alcohol over 80mg/dl

Blood alcohol level	Male	Female	Total
81–240mg/dl	147	16	163
241–400mg/dl	93	13	106
> 400mg/dl	8	1	9
TOTAL	248	30	278

Table 7.2C - The nine individuals with blood alcohol levels over 400mg/dl

Sex	Mechanism	Blood alcohol level (mg/dl)
male	house fire	417
male	house fire	417
male	RTC - pedestrian	420
male	low fall	426
female	fall down stairs	435
male	drowning	444
male	fall down stairs	450
male	RTC - bicyclist	460
male	house fire	463

Table 7.2D - Implication of alcohol according to mechanism of injury

Mechanism of injury	Male deaths implicating alcohol	Female deaths implicating alcohol	Total deaths implicating alcohol (% of mechanism)
RTC pedestrian	44/78 (56.4%)	5/45 (11.1%)	49/123 (39.8%)
RTC vehicle driver	30/123 (24.4%)	4/28 (14.3%)	34/151 (22.5%)
RTC vehicle passenger	11/49 (22.4%)	2/41 (4.9%)	13/90 (14.4%)
RTC motorcyclists & cyclists	5/37 (13.5%)	1/5 (20.0%)	6/42 (14.3%)
Burns and/or smoke inhalation	30/49 (61.2%)	10/33 (30.3%)	40/82 (48.8%)
Hanging	65/177 (36.7%)	2/30 (6.7%)	67/207 (32.4%)
Drowning	32/93 (34.4%)	6/35 (17.1%)	38/128 (29.7%)
Falls	76/174 (43.7%)	18/84 (21.4%)	94/258 (36.4%)
Other	71/197 (36.0%)	5/27 (18.5%)	76/224 (33.9%)
TOTAL	364/977 (37.3%)	53/328 (16.2%)	417/1305 (32.0%)

Table 7.2E - Causes of road traffic deaths amongst 123 pedestrians

Circumstances	Alcohol implicated	Alcohol not implicated	Total
Stepped out into road	36	33	69
Hit by out of control vehicle	4	5	9
Trying to cross illegally (e.g. motorway)	5	2	7
Blown by wind, or pulled by dog on lead	0	2	2
Circumstances unclear	4	32	36
TOTAL	49	74	123

Table 7.2F - Causes of road traffic deaths amongst 151 vehicle drivers

Circumstances	Alcohol implicated	Alcohol not implicated	Total
Driving at high speed / lost control	20	44	64
High speed lost control, no seat belt	3	10	13
Hit by other vehicle which lost control	4	8	12
Lost control under influence of drugs	2	2	4
Other vehicle lost control under drugs	2	0	2
Dangerous overtaking manoeuvre	1	5	6
Dangerous overtaking in other driver	1	15	16
Dangerous right hand turn	0	10	10
Driver apparently fell asleep	0	3	3
Driver collided with other sleepy driver	0	1	1
Hit by foreigner driving on right side road	0	1	1
Hit drunk pedestrian on motorway	1	0	1
Cause of collision unclear	0	18	18
TOTAL	34	117	151

Table 7.2G - Causes of road traffic deaths amongst 90 vehicle passengers

Circumstances	Alcohol implicated	Alcohol not implicated	Total
Driver lost control at high speed	7	28	35
Collision with a vehicle which lost control	0	13	13
High speed collision not wearing seat belt	5	11	16
Hit during dangerous right turn	1	5	6
Foreigner driving on right side of road	0	5	5
Driver attempted dangerous overtaking	0	3	3
Driver influenced by drugs lost control	0	2	2
Driver fell asleep	0	1	1
Driver of other vehicle fell asleep	0	1	1
Cause of collision unclear	0	8	8
TOTAL	13	77	90

Table 7.2H - Causes of 82 deaths due to smoke inhalations and/or burns

Circumstances	Alcohol implicated	Alcohol not implicated	Total
Cigarettes implicated	24	6	30
Cooker or heating appliance	15	0	15
Under influence of drugs	0	2	2
Other	1	34	35
TOTAL	40	42	82

Table 7.2I - Causes of the 258 deaths due to falls

Type of fall	Alcohol implicated	Alcohol not implicated	Total
Low falls (i.e. <<2 metres in height)	55	65	120
Falls down stairs	25	18	43
Mountaineering falls	0	20	20
All other high (>2m) falls	14	61	75
TOTAL	94	164	258

Discussion

The results of this study tend to confirm the views of those who challenge the traditional view of an accident as being an unpredictable, chance event. Most of the events resulting in fatal injury appeared to have resulted more or less directly from the actions of the individuals who died, or from some other individuals. The fact that human actions (sometimes definitely amounting to “error”) were responsible for so many deaths underlines the way that injury prevention measures have to target and modify human actions.

Amongst the background causes, alcohol appeared to hold a prominent role in the deaths of both men and women, although in keeping with what might be expected from other data (Gentilello et al., 2000), alcohol was implicated in more deaths amongst men than women. The extent to which alcohol was involved varied considerably between different mechanisms of injury. In keeping with previous studies, alcohol was implicated to a great extent in deaths from fires (Anderson et al., 1983; Trier, 1983; Runyan et al., 1992; Squires & Busuttill, 1995b), falls down stairs (Wyatt et al. 1999d), and amongst pedestrians in road traffic collisions (Rutledge & Messick, 1992; Hansen et al., 1996; Thomsen, 1996; Wyatt et al., 2000b). The potentially fatal combination of alcohol with cigarettes, unguarded drops, fast traffic or open water is obvious and is apparent from the results of this study.

Alcohol occupies a definite and integral position in western culture. Attempting to re-educate and substantially change alcohol-related behaviour is particularly difficult given its strong cultural position. The fact that there is

considerable evidence to support regular consumption of alcohol on the grounds of healthy living (Doll, 1997; Stockley, 1998) provides further excuses, if any be necessary, for continued excessive consumption. In 1992, in its "Health of the Nation" document, the UK government aimed for drastic reductions in the proportion of the adult population drinking above what are considered to be "sensible levels" (Department of Health, 1992). General practitioners, holding a unique position within the community, may be in a good position to both identify "problem drinkers" and to then help them to reduce their alcohol intake. Despite this, early indications have been that little progress has been made to reduce the number of individuals drinking above "sensible levels", a situation some claim has not been helped by a lack of training and support in these matters amongst general practitioners (Deehan et al., 1998). This situation might improve if general practitioners were provided with more training and resources, but given current constraints within the National Health Service, it is also worth considering other approaches.

It has been suggested that the ideal time to target an individual who is at risk of alcohol-related fatal injury is when they present to hospital with an alcohol-related non-fatal injury (Longabaugh et al., 1995). Evidence from both the USA and the UK tends to confirm that hospital workers in Emergency (A&E) Departments are well placed to identify and refer for treatment alcohol-dependent and problem-drinkers, although this process inevitably requires some extra resources (Cherpitel et al., 1996; Huntley et al., 2000). In addition, before such an approach is adopted more fully,

concerns about patient confidentiality and the potential denial of insurance coverage and settling of claims would also need to be carefully considered and addressed (Rivara et al., 2000).

Whilst it is generally accepted that alcohol predisposes to injury, some researchers have gone further and controversially claimed that alcohol may both result in more severe injuries after any given insult and may also adversely affect the physiological response and thereby also the eventual outcome after injury (Li et al., 1997; Milovanovic & DiMaio, 1999). Certainly, it is recognised that injured individuals who have consumed alcohol present more frequently with head injuries than injured individuals who have not consumed alcohol, although this may simply be largely a reflection of the mechanism of injury (e.g. a preponderance of falls amongst those who have consumed alcohol) (Honkanen & Smith, 1991). Similarly, it has been found that individuals under the influence of alcohol who present following road traffic collisions have higher ISS than those who have not consumed alcohol, although alcohol here may exerting an effect indirectly, by affecting the behaviour of those injured (e.g. non-use of available seat belts) (Andersen et al., 1990; Tulloh & Collopy, 1994).

There are good theoretical reasons why individuals who have chronic problems related to alcohol (e.g. cirrhosis, coagulation problems, heart disease, malnutrition) may have a reduced the ability to recover from serious injury. Similarly, in theory, acute alcohol consumption in association with injury may predispose to various complications, including aspiration of gastric contents and hypothermia.

Experimental animal laboratory studies indicate that acute alcohol consumption results in adverse physiological responses to trauma in that alcohol reduces cardiac output, increases susceptibility to haemorrhagic shock, increases pulmonary vascular resistance and affects brainstem respiratory centres (Garrison et al., 1984; Blomqvist et al., 1987; Zink & Feustel, 1995; Li et al. 1997). Despite this animal data, firm evidence relating to humans is distinctly lacking (Li et al., 1997).

Some of those who died had very blood alcohol levels. Although survival has been recorded in an individual with a blood alcohol level of 1500mg/dl (Johnson et al., 1982), it is generally accepted that death as a result of alcoholic poisoning can occur at blood levels in excess of 300mg/dl, particularly in individuals who are not used to consuming large quantities (Knight, 1996). Massively high blood alcohol levels can cause death by a direct depressive effect upon the respiratory centre and slightly less directly by other mechanisms such as postural asphyxia and regurgitation with aspiration of vomit (Knight, 1996). It is hardly surprising that many of those with the very highest alcohol levels in this study died at home, since many of the levels were so high that mobility would be expected to have been seriously impaired.

Considering the apparent prevalence of drug-taking amongst the Scottish population, it was notable how relatively infrequently the use of illicit drugs appeared to be directly implicated in causing traumatic deaths in this study (Scottish Office Statistical Bulletin, 1997b). Certainly, this may reflect the true role of drugs, but on the other hand, may reflect the fact that the various drugs of potential abuse were not carefully searched for in every case. Compared with alcohol, attempting to

ascertain the role of a particular drug in causing a traumatic death is not necessarily easy. Whereas ingestion of a particular amount of alcohol produces reasonably predictable blood levels, which decay and disappear in a relatively predictable fashion, the same is not true of many drugs of abuse (Knight, 1996). Metabolites of cannabis, for example, remain detectable within the bloodstream for days and even weeks after ingestion (Knight, 1996). Interpretation of blood levels of certain drugs is thus made rather difficult and made more difficult by the fact that trying to determine the effect of various drugs upon the ability to safely perform certain complex tasks (such as driving a motor vehicle) is not necessarily easy (Ledingham, 1999). It is widely acknowledged amongst police surgeons (forensic medical examiners) that whereas it may be relatively easy to prove impairment of driving ability amongst individuals who have even modest blood levels of alcohol, it can be extremely difficult to show similar impairment amongst individuals whose blood contains drugs of abuse and their metabolites.

7.3 Conclusions

It is clear that the greatest potential for reducing deaths from trauma lies with prevention. Preventative measures may be largely responsible for the steady decline in the number and severity of road traffic collisions, despite increased road usage (Department of Transport, 1994). These preventative measures may include public education, legislation, developments in road safety engineering and technological advances in motor vehicle design (McDermott & Hough, 1979; Committee on trauma research, 1985; Bodiwala et al., 1989).

Alcohol appears to occupy a central role in the causation of a large proportion of fatal injuries. In addition, alcohol may, in certain circumstances, also reduce the chances of survival after injury by impairing the ability of those involved to obtain urgent help and to apply simple emergency first aid measures. Although there appear to be no acceptable simple solutions, efforts to combat the role of alcohol in deaths from trauma need to continue and perhaps more imaginative approaches be sought out and tried.

Prevention of occupational injuries and deaths should remain a priority for those involved in producing and enforcing legislation for the workplace. For the prevention of some traumatic deaths, including homicides and suicides, the way forward is less clear (Wilkinson, 1994). However, the size and nature of the problem demands that attention continue to be directed towards preventative efforts.

Chapter 8 - The potential to save lives through improved prehospital care

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- 8.2 Unlikely survival after medical treatment on scene - a case report page 285
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8.1 Treatment issues in the prehospital

environment

The prehospital environment is very different from the hospital environment. However, judging by the staggering increase in emergency calls for emergency ambulances, the increasing demand for emergency prehospital care appears to mirror that observed in the A&E departments of hospitals throughout the UK (Carney, 1999). Paramedics, ambulance officers, military doctors and some general practitioners are trained to treat patients who have sustained trauma in the prehospital setting, but with a very few notable exceptions, hospital-based doctors and nurses are not.

There is a powerful appeal to the idea of providing life-saving treatment at the scene of injuries and/or in transit to hospital. This appeal is encouraged by a group of well-motivated enthusiasts. In its White Paper "Saving lives: our healthier nation" the UK government boasted "frontline ambulances now have a fully qualified paramedic" and claimed "patients cared for by paramedics recover better than patients who are not" (Secretary of State for Health, 1999). Despite this enthusiasm for prehospital care, the idea that prehospital trauma care saves lives remains controversial. This chapter examines the perspectives of both the trauma patient and the trauma team, and reviews these in the context of the available evidence relating to prehospital care.

8.2 Unlikely survival after medical treatment on scene - a case report

Prehospital care

A 30 year old female car driver collided with the rear of a stationary bus, at an estimated speed of 60-70 miles per hour. She was restrained by a seat belt, but the car was not fitted with an air bag. The impact produced considerable intrusion of the vehicle into the driver's compartment of her car, causing entrapment. The emergency services requested the assistance of the local hospital based flying squad ("Medic One").

On arrival of "Medic One", her pulse rate was 140 beats per minute, her blood pressure was unrecordable, her respiratory rate was 8 breaths per minute and she was deeply unconscious (GCS of 4/15, comprising E1, M2, V1). Her pupils were 4mm in diameter, equal, non-reactive and divergent. She was already receiving oxygen by face mask and a hard cervical collar had been applied. Deformation of the vehicle caused her to be trapped upright in the driver's seat by the lower limbs. Initial examination revealed a compound fracture of the right mandible with loose teeth and blood partially obstructing her upper airway. There was palpable left sided chest wall crepitus, but with bilateral air entry on auscultation. There were compound fractures of the right elbow and both femoral shafts.

Two large bore intravenous cannulae were inserted and rapid infusion of crystalloid and colloid was commenced. The patient was extricated from her vehicle with the help of the Fire Service. In view of worsening airway obstruction, major chest injury and hypoventilation, a rapid sequence induction was performed at scene. Tracheal intubation was achieved with in-line cervical immobilisation. After splinting her lower limbs, she was transferred by ambulance to the A&E department (journey time of approximately 25 minutes).

Hospital care and subsequent course

On arrival in A&E, evaluation and resuscitation continued together. Amongst other findings (see table), she was found to have a widened mediastinum and nasogastric tube deviated to the right on chest X-ray which, combined with other clinical features and the fact that she remained hypovolaemic despite resuscitation, prompted emergency thoracotomy. Thoracotomy revealed haematoma and cardiac tamponade secondary to a laceration of the superior vena cava at its junction with an aberrant right mammary vein. Surgical repair was successful and was the first of a series of surgical procedures required to treat her associated orthopaedic and facial injuries (see table 8.2A).

She experienced a stormy post-operative period lasting more than a month, during which time she developed adult respiratory distress syndrome and required treatment on intensive care. She was transferred from intensive care on the 50th post-

operative day and slowly made a good recovery, at the end of which she was alert and orientated with no detectable neurological deficit.

Table 8.2A - Summary of injuries and their AIS

Anatomical injury	AIS score
<u>Head and neck:</u>	
• avulsed incisor tooth	1
<u>Face:</u>	
• bilateral compound fracture mandible	2
• Le Fort II facial injury	2
• full thickness laceration right upper lip	1
<u>Chest:</u>	
• bilateral pulmonary contusions	4
• torn internal mammary vein at junction with superior vena cava	3
• multiple fractures right ribs with torn pericardium and tamponade	3
• extensive bruising to chest wall	1
<u>Abdomen:</u>	
• retroperitoneal retrocaecal haemorrhage	3
• small tears of the liver with some haemorrhage	2
<u>Extremities:</u>	
• compound bilateral femoral shaft fractures	3
• compound fracture right humeral shaft and elbow with bone loss	3
• comminuted fracture right patella	2
• fracture right clavicle	2
<u>External:</u>	
• multiple skin abrasions	1

TRISS analysis

The aforementioned physiological data at scene and the anatomical injuries scored according to the Abbreviated Injury Scale, 1990 revision (see table 8.2A), enabled TRISS analysis using UK coefficients for blunt trauma as follows:

RTS calculation

GCS = 4 → code: 1 x weight (0.9368) = 0.9368

Systolic BP = unrecordable → code: 0 x weight (0.7326) = 0.0

Respiratory rate = 8 → code: 2 x weight (0.2908) = 0.5816

$$\text{RTS} = 0.9368 + 0.0 + 0.5816 = 1.5184$$

ISS calculation:

$$\begin{aligned} \text{ISS} &= 4^2 + 3^2 + 3^2 \\ &= 34 \end{aligned}$$

Ps calculation:

$$\text{Probability of survival (Ps)} = 1/(1+e^{-b})$$

where “e” is the natural logarithm and $b = b_0 + b_1(\text{RTS}) + b_2(\text{ISS}) + b_3(\text{A})$

“A” is a weighting factor to allow for the age of the patient

b_0, b_1, b_2, b_3 are weighted coefficients (see chapter 2.7)

$$b_0 = -1.247$$

$$b_1 = 0.9544$$

$$b_2 = -0.0768$$

$$b_3 = -1.9052$$

$$A = 0$$

$$\text{Thus, } b = -1.247 + (0.9544 \times 1.5184) + (-0.0768 \times 34) + (-1.9052 \times 0)$$

$$= -1.247 + 1.449 - 2.611 - 0$$

$$= -2.409$$

$$\text{Ps} = 1/(1+e^{-b})$$

$$= 1/(1+11.123)$$

$$= 1/(12.123)$$

$$= 0.0825 \text{ (8.25\%)}$$

Discussion

This patient had multiple injuries, of which the thoracic injuries were the most serious. On arrival of the flying squad to the scene of the collision, she was trapped and had two immediately life-threatening problems: an obstructed airway and gross hypovolaemic shock. Prehospital tracheal intubation with the assistance of anaesthetic drugs was used to secure the airway, whilst hypovolaemia was temporarily treated with intravenous fluids, before definitive surgery at hospital.

Superior vena caval laceration following blunt trauma is a rare and often fatal injury, requiring urgent surgical intervention (Kudsk et al., 1984). TRISS analysis yields an expected survival of 0.0825 (8.25%) and so this patient is clearly an unexpected survivor. Whilst the role of the A&E department, thoracic surgery department and intensive care unit is acknowledged as being critical to the positive outcome, the members of the hospital-based flying squad believed their interventions to be life-saving, arguing that it would have been most unlikely that she would have survived to reach hospital without advanced medical intervention (particularly bearing in mind that paramedics in the UK cannot administer sedative nor neuromuscular blocking agents). Whether the flying squad did affect her outcome cannot, of course, be proven, but until some hard evidence emerges, it is easy to see why enthusiastic physicians will continue to treat patients following trauma in the prehospital setting.

8.3 Data from a hospital based flying squad

Introduction

Since the inception of the first hospital based flying squad in Derby in 1955 (Collins, 1966), enthusiasts have reported an increasing demand and an expanding role for such teams (Rowley & Collins, 1979; Robertson & Steedman, 1985). Many reports have suggested a subjective benefit for patient outcome associated with flying squads, (Snook, 1972; Gorman & Coals, 1983; Cope et al., 1991; Graham et al., 1996), but there has been a distinct failure to produce objective data to support this viewpoint (Robertson & Steedman, 1985; Steedman, 1990). A considerable portion of previous work is based on retrospective data (Rowley & Collins, 1979; Gorman & Coals, 1983; Steedman & Robertson, 1986; Dark et al., 1990; Cope et al., 1991). This study prospectively investigates the activities of the flying squad of the Royal Infirmary of Edinburgh.

Background information

The A&E Department in the Royal Infirmary of Edinburgh is the largest unit in south-east Scotland and serves a population of over 500,000. Since its inception in 1980, the fundamental composition of the flying squad has not altered. A specially modified ambulance vehicle with a range of resuscitation equipment and

communication links is available on a 24-hour, 365-day basis. The responding team consists of a minimum of a team leader (either an A&E consultant or specialist registrar), one senior house officer, one senior nurse and a paramedic. The vehicle is driven by ambulance personnel. This team may be augmented as necessary for complex incidents. Requests for the squad to be activated are accepted from any of the emergency services or from a medical practitioner, with all calls being co-ordinated through ambulance control.

Methods

A structured proforma was designed to allow accurate prospective data collection during a six month study period. The proforma was introduced in August 1996 and was completed by the medical team leader for each call. Prehospital data recorded included the nature and location of the incident, the source of the request, the distance, time to scene and the composition of the team. All basic and advanced interventions performed by both the first attenders and "Medic 1" were recorded.

The subsequent in-hospital course of each patient was obtained from A&E notes, ward charts, operative records and relevant post-mortem reports. Standard outcome measures of survival to discharge, days in hospital and mortality rates were derived. Further data was available on those patients who had sustained trauma from the STAG (Little et al., 1995; chapter 2.6). This enabled ISS and RTS to be calculated and Ps to be derived using TRISS methodology (Boyd et al., 1987). In

addition to these objective measurements, each senior doctor was allowed an opportunity to document if they subjectively considered that the actions of the flying squad contributed favourably to patient outcome.

Results

During the six month study period there were 123 requests for “*Medic 1*” and in total 97 patients were treated. On 43 occasions the team were “stood down” en route (i.e. its services were no longer considered necessary by the attending emergency crews.) Table 8.3A outlines the profile of the calls. The team leader was a consultant in 14 calls and a registrar in the remaining cases. These were accompanied by a senior house officer on 73 occasions and a member of nursing staff in 109 instances. Various trainees attended 22 incidents. The source of the requests and associated “stand-downs” are outlined in table 8.3B.

The squad was activated for 22 patients in non-traumatic cardiac arrest. 17 of these patients died at scene. Five patients were transferred to hospital but none survived to discharge. Only two patients were in ventricular fibrillation on arrival of the team. Of these, one patient survived to hospital, but died within 24 hours. All patients treated had both basic and advanced life support interventions performed including mechanical ventilation and chest compression, peripheral and central venous cannulation and administration of appropriate cardiac drugs. On two

occasions the attending crew sought assistance for airway control. In seven of the 22 cases, the squad was requested because of difficulty with access or extrication.

The squad responded to 13 patients of “miscellaneous” aetiology (table 8.3C). Within this group two patients died in hospital, a 65 year male with a ruptured abdominal aortic aneurysm and a 65 year male with severe obstructive airway disease who died four days later in Intensive Care. The remaining patients were discharged from hospital without complication.

The most common traumatic cause for activation of the squad was a road traffic collision. Medic One treated 47 road accident casualties, of whom 27 were trapped at the time of mobilisation. Table 8.3D summarises the trauma calls. Of the seven deaths amongst the group of trauma patients, in this group, six were in cardiac arrest on arrival of Medic One. Table 8.3E outlines the prehospital interventions undertaken by Medic One for injured patients.

Twenty-two trauma patients fulfilled the criteria allowing TRISS analysis by STAG. Table 8.3F summarises the outcomes of these patients. All these patients survived to discharge and included two unexpected survivors as calculated by TRISS methodology. Subjectively the team leaders believed their intervention to be “critical” in seven cases: three had a rapid sequence induction and definitive airway management performed at scene, two patients had treatment for hypovolaemia not recognised by the first prehospital responders and two patients had their extrication expedited.

The remaining 38 trauma patients were discharged without complication, with

the longest hospitable stay being two days. Fifteen patients sustained minor head injuries, 14 patients had uncomplicated fractures, and the remaining nine patients had soft tissue injuries. The team leader believed their intervention to be of benefit in five of these patients, as they required intravenous opioid analgesia at scene to allow extrication and transport.

Table 8.3A - Profile of calls

Type	Number of calls	Number of patients
Trauma	44	61
Non-traumatic cardiac arrest	22	22
Other	14	14
Stand-downs	43	0
Total	123	97

Table 8.3B - Source of calls

Source	Number of calls	Number of stand-downs
Ambulance control	55	39
Ambulance crew at scene	53	2
General practitioner	3	0
Police	6	2
Fire service	3	0
Other hospital	3	0
TOTAL	123	43

Table 8.3C - Miscellaneous conditions

Condition	Number of patients
Status epilepticus	4
Asthma	2
Respiratory arrest	1
Abdominal aortic aneurysm	1
Upper gastrointestinal bleed	1
Arrhythmia	1
External haemorrhage	1
Inter-hospital transfers	2
No data available	3

Table 8.3D - Trauma calls

Cause	Number of calls	Number of patients
Road traffic collisions	30	47
Falls	8	8
Assaults	1	1
Other	5	5
TOTAL	44	61

Table 8.3E - Medic One treatments for trauma patients

Type	Number of patients	Number of deaths
Basic life support	7	6
Mechanical cardio-pulmonary resuscitation	4	4
Ventilation (with chest compressions)	11	7
Tracheal intubation	6	2
Rapid sequence induction	3	0
Intercostal drain	1	1
Needle thoracocentesis	2	2
Pericardiocentesis	1	1
Intravenous cannulation	47	6
Intravenous fluids	33	7
Intravenous analgesia	26	0
Central venous access	4	4

Table 8.3F - Outcome for trauma patients analysed by STAG

ISS range	Median inpatient days	Median ITU days	Median HDU days	Median RTS	Median Ps (%)
(No.)	(Range)	(Range)	(Range)	(Range)	(Range)
1-8 (4)	5 (4-6)	0 (0)	0.5 (0-1)	7.84 (7.84)	98.30 (97.0-99.6)
9-15 (9)	10 (4-50)	1 (0-2)	3 (1-4)	5.96 (4.09-7.84)	98.62 (7.4-99.25)
16-75 (9)	15 (8-59)	2.5 (0-45)	2 (0-3)	6.9 (0.87-7.84)	73.32 (7.4-97.18)

Discussion

The data confirm that the flying squad of the Royal Infirmary of Edinburgh is mobilised by the urban emergency services on a regular (almost daily) basis. This allowed the attending teams to experience the practical realities of co-operating with their counterparts in the ambulance, fire and police services. Operations occurred at various times during the day and night, in a spectrum of weather conditions and geographical locations. The mobile teams therefore experienced a range of scene conditions. This undoubtedly presented a valuable training and educational opportunity, and encouraged enhancement of team skills in the prehospital environment.

Hospital-based prehospital teams may confer a benefit to patients in terms of providing continuity of care. On arrival at hospital, team members liaise directly with the team leader in the resuscitation room and assist with the initial care of the patient. Additionally, they provide accurate first-hand information on the mechanism of injury and are aware of the potential for major injuries.

The outcome for patients in cardiac arrest attended by "Medic One" underlines the poor prognosis associated with advanced life support techniques when basic life support and defibrillation have failed, reflecting previous work (Guly et al., 1995). Whilst the team involvement had no positive benefit in terms of mortality, the senior medical presence may assist when difficult decisions have to be made.

The variety of disease aetiologies and small numbers involved in the miscellaneous group in this study ensures that reliable data interpretation cannot be

achieved. Non-trauma conditions are difficult to assess objectively as there are no validated methods to assess patient outcome for such diverse conditions. Certainly, patients had a variety of advanced interventions performed at the scene, enabling valuable training opportunities.

Only 22 of the trauma patients fulfilled the standard criteria allowing objective TRISS analysis (Boyd et al., 1987). It is impossible to extrapolate conclusions from such a small group of patients. Furthermore, it is difficult to identify the isolated effect of the flying squad on outcome without reference to advanced resuscitation in A&E and subsequent care in other parts of the hospital. Having said this, it is encouraging that amongst those treated for trauma by the flying squad there were no unexpected deaths, but two unexpected survivors according to TRISS methodology using UK coefficients (Boyd et al., 1987).

Twenty-six of the trauma patients received prehospital intravenous opioid analgesia and whilst this single intervention did not demonstrably affect outcome, it is beneficial to patient care and well-being (Wyatt, 1993). Intravenous analgesia provided by a physician has potential advantages over that provided by UK paramedics in that the former can administer any of a wide range of opioid analgesics, whereas paramedics are limited to the use of nalbuphine (Hyland-McGuire & Guly, 1998). Nalbuphine is a partial agonist opioid analgesic and can therefore theoretically complicate subsequent administration of other opioids, although the extent to which this is a problem in practice is debatable (Houlihan et al., 2000; Volans, 2000).

Prehospital care continues to stimulate questions and debate with regard to a uniform and optimum system of care (Smith et al., 1985; Gold, 1987; Sampalis et al., 1993; Cooke, 1999). Whilst few would argue against the benefits of rapid basic prehospital measures (such as provision of oxygen, application of bandages and hard cervical collars) (Ali et al., 1997), there is evidence to suggest that potential benefits of providing extended techniques on-scene for some patients may be more than offset by prolonged scene times and delays in transfer of patients to an appropriate facility (Sampalis et al., 1993; Bickell et al., 1994). These arguments are particularly persuasive where prehospital transfer times are short (Cayten et al., 1993). Recent research in the UK has failed to show an improvement in trauma patient mortality with advanced techniques of intravenous access and fluid administration, perhaps by one or more of the following mechanisms: delay in reaching hospital, accelerated haemorrhage secondary to increased blood pressure and mechanical dislodgement of blood clot, dilution of natural clotting factors, diminished clot quality (Rainer et al., 1997; Nicholl et al., 1998; Brazil, 2000). Advanced airway control with anaesthetic agents is an achievable prehospital intervention, but it is difficult to find much supportive evidence, in terms of an associated improved mortality rate therefrom. More work is necessary to determine whether drug-assisted intubation affects morbidity or mortality, especially in the context of major head injuries. However, it is recognised that airway obstruction is a major factor in a proportion of prehospital deaths (Yates, 1977). Given the potentially rapidly fatal effect of airway obstruction, it seems logical that if any impact is to be made on this, airway and breathing

problems should be dealt with on scene (Deakin et al., 1994; Hussain & Redmond, 1994). Previous work on prehospital airway management has claimed that there is a continuing role for medically delivered airway care (Xeropotamos et al., 1993; Hussain & Redmond, 1994; Graham & Meyer, 1997; Graham et al., 1997), although some claims may have been exaggerated (Nicholl, 1994). Further prospective large scale studies are required to identify the optimum level of prehospital interventions in the UK, and equally importantly, who should deliver it.

8.4 The evidence for advanced prehospital care

Discussions about prehospital care become understandably passionate amongst those who have been involved in providing this form of care and amongst those who have received it. Data in this thesis (chapters 3.1 and 3.2) indicate that a high proportion of those who die before reaching hospital are found dead and many have unsurvivable injuries (Wyatt et al., 1995; Wyatt et al., 1997a). Similarly, very few patients (either adults or children) die in transit or at scene having been found alive (Wyatt et al., 1995; Wyatt et al., 1997a). Therefore, the potential for improved prehospital medical intervention to save lives appears to be small. It has been suggested that there is less scope to salvage injured individuals in the prehospital setting in the UK compared with the USA because a much higher proportion of serious trauma in the UK is blunt, rather than penetrating (Limb et al., 1996). In those rural parts of the USA where penetrating trauma is less prominent, greater distances from hospital inevitably result in greater prehospital times, which when combined with the knowledge that victims of trauma in prehospital areas have seven times the risk of dying before reaching hospital than those in urban areas, supports the case for advanced prehospital care (Maio et al., 1996; Grossman et al., 1997).

Data from drowning deaths in south-east Scotland (chapter 4.4) identified one area where prehospital resuscitation can be improved, although the chief deficiency here was a failure to commence and continue basic, rather than advanced, prehospital resuscitation (Wyatt et al., 1999c). Similarly, few would argue of the benefit of

ensuring adequate simple prehospital measures, such as the administration of oxygen, the use of suction, appropriate oropharyngeal airways and cervical immobilisation (Arreola-Risa et al., 2000).

The value of advanced prehospital care in the UK cannot simply be dismissed on the basis of the number of deaths in transit or at scene after being found alive. It can of course be argued that timely and aggressive prehospital resuscitation improves patient outcome by preventing late deaths from multi-organ failure. Standard guidelines on the measurement of head injury continue to emphasise the importance of avoiding the secondary insults that accompany hypoperfusion (Bullock et al, 1996). Similarly, there are claims that delayed correction of occult hypoperfusion within the first 24 hours following blunt trauma results in a worse outcome (Blow et al., 1999; Claridge et al., 2000). However, (as outlined in chapter 4.5) there is also evidence to suggest that some forms of prehospital resuscitation (e.g. the routine prehospital administration of intravenous fluids for penetrating trauma) may actually be detrimental in certain types of trauma (Bickell et al., 1994; Novak et al., 1999). As a result of this evidence, the Joint Royal Colleges Ambulance Service Liaison Committee have proposed guidelines for prehospital intravenous cannulation of trauma patients (Nolan, 1999).

One factor relevant in arguments concerning prehospital care is that distances from scenes of injury to hospital in the UK tend (with some notable exceptions) to be relatively small. Prehospital times may be considerably extended for individuals who are trapped at scene, particularly after road traffic collisions, providing some

justification for hospital-based flying squads in this situation. Despite the well-developed rescue helicopter system in Germany (Haas et al., 1995), the role of the UK urban helicopter remains controversial, particularly since transit times from scene to hospital tend to be relatively small in the UK (Nicholl et al., 1994; Nicholl et al., 1995b; Cunningham et al., 1997).

Hospital-based flying squads do offer benefits in terms of team performance and direct liaison with the relevant emergency services. This provides opportunities to educate and train for major incidents, disasters and difficult extrications. Objective study of outcome following trauma management in the prehospital setting can use validated TRISS methodology, but interpretation is limited by relatively small patient numbers. Inevitably, enthusiasts will continue to provide prehospital care, justifying it by anecdote and personal opinion. Although there are increasing demands for prehospital care practice to be evidence based, this may be difficult to achieve (Hodgetts & Cooke, 1998; Brazier et al., 1999).

**Chapter 9 - The potential for improved hospital care
to reduce the number of deaths**

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9.2	Analysis of trauma outcome of STAG hospitals	page 312
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9.1 Introduction

The data in chapter 3 reveals that the majority of individuals who die after trauma in Scotland never reach hospital. However, relatively large numbers of patients do die in hospital following trauma, hence the importance of ensuring that patients who reach hospital alive receive the best treatment.

Having acknowledged the need to assess the hospital treatment provided for injured patients, the obvious question is how to do it. Review of case records is a relatively easy, if time-consuming, undertaking, but is understandably somewhat subjective in nature. Also, a review limited solely to those cases where the patient died may highlight deficiencies, but does not reveal the positive areas of high quality care. As described in chapter 2.7, TRISS methodology can prove to be a useful tool to compare actual patient outcomes after trauma with expected (or predicted) outcomes (Wyatt et al, 1988a). Similarly, comparison of large cohorts of patients allows an insight into the quality of trauma care provided by one hospital when compared against others. In this chapter, TRISS methodology is used to explore the potential to reduce the number of hospital deaths following trauma.

9.2 Differences in trauma outcome between hospitals

Background

This study uses TRISS methodology to examine the performance of Scottish hospitals to see how much apparent variation exists between hospitals and to see how the performance of individual hospitals appears to have altered over time. From the results it is hoped to identify how much potential exists to improve trauma care in Scotland and thereby reduce the number of deaths.

Methods

Data was collected prospectively by STAG in hospitals throughout Scotland on patients presenting following trauma and whom required admission to hospital or who died in the A&E department (chapter 2.6). Data collected on each patient included age, mechanism of trauma, anatomical injuries sustained, physiological derangement on hospital presentation and outcome in terms of survival or death. From this data ISS, RTS and Ps were calculated for each patient, enabling comparisons between actual and expected outcomes to be made for each patient (chapter 2.7). Further analysis using TRISS methodology allowed W-statistics to be

calculated for each hospital, thereby allowing comparisons of outcomes between hospitals and against the UK average (chapter 2.7).

Data was collected over two consecutive years for eighteen Scottish hospitals, enabling an insight into the alteration in outcome within these hospitals over time. The results in terms of actual outcome compared with expected outcome (W-statistics) for those hospitals which had complete data collection for the year 1994/5 allowed these hospitals to be ranked in order of “performance” (table 9.2B). Having identified the best performing hospital, it was possible to compare against the performances of the other hospitals and to calculate for each of them the number of theoretical lives which would have been saved if each of the other hospitals had actually matched the best performing hospital. This calculation took into account differences in W-statistics and the number of trauma patients who presented.

Results

The W-statistics of the first four hospitals which collected data for STAG over time is shown in figure 9.2(i). The performances (as measured in the form of W-statistics) for 18 Scottish hospitals in which data was collected over at least two consecutive years are shown in table 9.2A. Eleven of these 18 hospitals improved their W-statistics from the year when data was first collected to the last year of data collection (1999).

The W-statistics of the eight hospitals with complete data for the year 1994/5 is shown in table 9.2B. Hospital "1" had the best performance during the year. Comparing the W-statistics of each of the other hospitals against hospital 1 and taking into account the number of trauma patients each hospital saw during the year, enabled a calculation to be performed which yielded the theoretical number of lives which would have been saved had each of the hospitals performed as well as hospital 1. The total number of "theoretical lives saved" in the eight hospitals amounted to 32.10 (table 9.2B). The A&E departments in these eight hospitals provide cover for a population of approximately 2.7 million people, 52% of the total Scottish population of 5.1 million people. Assuming a similar range of W-statistics amongst the other Scottish hospitals, a reasonable estimate of the possible number of lives which could be saved if the performance of managing all Scottish hospitals matched that of the best would therefore be 64 lives.

Figure 9.2(i) - Performance of the original four STAG hospitals over time

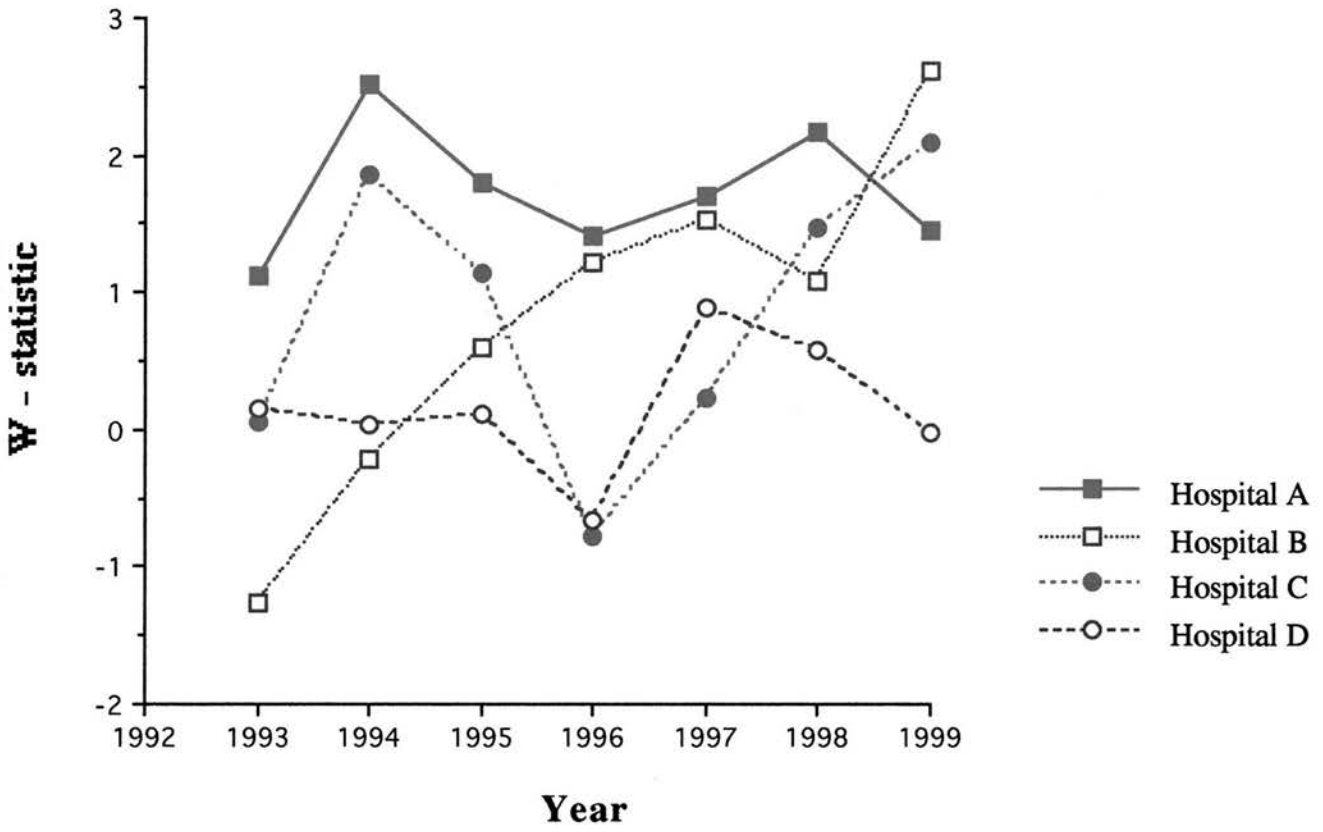


Table 9.2A - Performance of Scottish hospitals over time

Hospital	Initial W-statistic (year)	Latest W-statistic (year)	Improvement?
A	1.12 (1993)	1.45 (1999)	yes
B	-1.26 (1993)	2.61 (1999)	yes
C	0.06 (1993)	2.09 (1999)	yes
D	0.88 (1993)	1.62 (1999)	yes
E	0.16 (1993)	-0.03 (1999)	no
F	-2.30 (1995)	0.08 (1999)	yes
G	1.25 (1996)	1.07 (1999)	no
H	0.81 (1996)	-0.14 (1999)	no
I	1.33 (1996)	-0.14 (1999)	no
J	-0.55 (1996)	1.52 (1999)	yes
K	2.29 (1997)	2.35 (1999)	yes
L	0.80 (1997)	1.21 (1999)	yes
M	0.70 (1997)	0.45 (1999)	no
N	-0.25 (1997)	1.47 (1999)	yes
O	1.25 (1997)	1.02 (1999)	no
P	1.24 (1997)	0.52 (1999)	no
Q	1.81 (1997)	2.36 (1999)	yes
R	-0.78 (1998)	1.59 (1999)	yes

Table 9.2B - W-statistics of 8 hospitals in 1995 and theoretical lives saved

Hospital	W-statistic	Theoretical number of lives which would be saved if W-statistic was improved to the level of the best performing hospital (1)
1	2.1527	0
2	1.6811	1.41
3	1.6694	4.33
4	1.2803	4.85
5	0.9798	5.01
6	0.1183	2.54
7	-0.4272	8.10
8	-1.048	5.86
		Total = 32.10

Discussion

Data from the USA suggests that the presence of a state trauma system may reduce the risk of death caused by injury and that this reduction is particularly evident in relation to road traffic deaths (Nathens et al., 2000). Similarly, claims have been made regarding large numbers of lives which could be saved by having formal trauma centres in the UK (Yates, 1988; Court-Brown, 1990; Redmond, 1993; Redmond et al., 1993). The evidence, however, remains inconclusive about the North Staffordshire Trauma Centre (Nicholl et al., 1995a; Nicholl & Turner, 1997).

Having said all this, there is definite evidence from UK MTOS that there is a wide variation in outcome following trauma in the UK (Yates et al., 1992; Woodford et al., 2000). MTOS UK study is open to criticism in that a large proportion of eligible trauma victims are not entered into the database and that as a result, the W-statistics from various hospitals might be inaccurate. The same criticism cannot be levelled at data collected by STAG throughout Scotland, since more than 90% of eligible individuals are entered into the STAG database (Little et al., 1995). In addition, the STAG database includes all deaths from trauma (Little et al., 1995; chapter 2.6).

The wide variation in outcomes after trauma in various Scottish hospitals revealed in the data above implies that there is some potential for some hospitals to improve their treatment to reach the levels which are achievable elsewhere. Using the outcome achieved by the best performing hospital as a "general target" is reasonable in that these levels of results are achievable within the same trauma population. The

argument that such a target is unreasonable to apply to all hospitals, because those hospitals seeing larger numbers of injured will naturally have better outcomes is not supported by evidence from the USA (Cooper et al., 2000). The estimate derived from the data presented of there being potential to save 64 lives per year in Scotland is considerable, but remains relatively small when seen in relation to the overall number of trauma deaths in Scotland per year. Despite the fact that there is clearly far more potential to prevent trauma deaths by injury prevention than by improving hospital treatment, analysis of outcome of hospital treatment solely in terms of survival or death is rather a crude approach. Consideration also needs to be given to the fact that differences in treatment can result in differences in long-term morbidity amongst survivors, although at present there is no generally accepted validated tool available to analyse such differences.

9.3 Association between A&E doctor seniority and outcome after trauma

Background

From a historical perspective, there can be no doubt that, until recently, there has been relatively little interest in trauma management in the UK (Court-Brown, 1995). Deficiencies in the management of patients with trauma in the UK in the past have been well publicised and highlighted (Royal College of Surgeons of England, 1988; Anderson et al., 1988; Court-Brown, 1989; Yates, 1992). Retrospective review of 1000 deaths after trauma by the Royal College of Surgeons of England concluded that some deaths were unnecessary and that many were associated with delivery of emergency care by inexperienced doctors (Royal College of Surgeons, 1988). These conclusions were based upon subjective retrospective analysis of case notes - objective evidence based upon prospective data regarding the importance of experience of the resuscitating team is somewhat lacking.

The focus regarding the initial reception and resuscitation of the injured patient has naturally fallen upon the senior doctor ("team leader") who directs the initial resuscitation effort in the A&E department. As a result, Advanced Trauma Life Support courses aimed at improving the efforts of the resuscitating trauma team leader were introduced by the American College of Surgeons and have become very popular and recommended in the USA, UK and elsewhere (American College of

Surgeons, 1988; Ali et al., 1993; Skinner, 1993). Also, some hospitals in the UK have dramatically altered their A&E staffing levels and work patterns in order to increase the immediate availability of experienced doctors to manage seriously injured patients (Redmond et al., 1993). Unfortunately, attempting to elucidate the effect of the presence of senior staff within such hospitals is difficult (Nicholl et al., 1995a; Nicholl & Turner, 1997). Comparing patients' outcomes with those in other hospitals yields information about the effectiveness of different systems of care within two different hospitals, which may be influenced by numerous other factors apart from differences in seniority of accident and emergency staff (Nicholl et al., 1995a; Nicholl & Turner, 1997). In order to try to investigate the way in which the level of seniority of accident and emergency (A&E) doctor influences outcome after trauma, different cohorts of patients treated within the same hospitals need to be compared.

Patients and methods

The trauma care delivered in four Scottish hospitals (Edinburgh Royal Infirmary, Aberdeen Royal Infirmary, Glasgow Western Infirmary and Glasgow Royal Infirmary) was studied prospectively by STAG between February 1992 and December 1996. Criteria for inclusion in the study were those used previously by MTOS, which specifically exclude children aged less than 13 years and elderly patients with isolated (osteoporotic) neck of femur fractures or isolated fractures of

the pubic rami (Yates et al., 1992). Data collected included the physiological state of 10,968 patients at hospital presentation, together with the anatomical injuries sustained, from which RTS and ISS were derived respectively (Baker et al., 1974; Champion et al., 1989; AAAM, 1990). These scores enabled individual probabilities of survival to be calculated using TRISS methodology (Boyd et al., 1987). Analysis of actual deaths against expected deaths in the form of a W-Statistic allowed the management of different cohorts of patients to be compared (Boyd et al., 1987). Continuous, non-normally distributed variables were analysed using the Mann-Whitney U test. Categorical variables were analysed using the chi squared test. The data capture rate for the study was 94%. Complete physiological data was available for all patients. All those who died as a result of their injuries were included.

Details of the most senior A&E doctor involved in treating each patient who presented following trauma were prospectively collected. This allowed all patients to be classified according to whether or not an A&E consultant had been involved in their management at any stage in the A&E department. The accuracy of the data collected was checked daily in each hospital by independent local staff employed by STAG.

Results

The 1208 patients treated by an A&E consultant had a significantly better outcome than the 9195 patients treated by junior staff (figure 9.3(i)). Although significantly ($p<0.01$) more patients seen by a consultant presented to A&E during 'normal' working hours (Monday-Friday, 9a.m.-5p.m.), analysis of outcome according to time of presentation revealed that the difference in outcome associated with consultant presence was more exaggerated outside than during "normal working hours" (figure 9.3(ii)). Further analysis of outcome according to grade of junior doctor is shown in figure 9.3(iii).

There was no significant difference in the pre-hospital times (time ambulance called to time arrived in hospital) between the consultant group (median pre-hospital time 50 minutes) and the non-consultant group (median pre-hospital time 51 minutes). The patient group treated by consultants was significantly ($p<0.01$) younger and significantly different in that it comprised more males, more patients who had suffered a road traffic collision or high fall and fewer who had had a low fall or sporting accident. ISS in the consultant group were significantly higher, RTS and Ps significantly lower. Overall, significantly fewer patients ($p<0.01$) spent more than two hours in A&E. This finding was true even allowing for differences in severity of trauma - of those 1427 patients with major trauma (ISS >15), the 503 patients treated by a consultant had a median time in A&E of 100 minutes, compared with 128 minutes for the non-consultant group ($p<0.05$). In addition, patients with major trauma treated by a consultant were significantly more likely ($p<0.01$) to have

involvement of consultants from other specialties (including intensive care, general and orthopaedic surgery) than those patients not treated by an A&E consultant (28% compared with 13% respectively). Similarly, a significantly higher proportion ($p < 0.01$) of patients with major trauma treated by an A&E consultant were transferred to the intensive care unit, compared with those not treated by an A&E consultant (55% compared with 40% respectively).

Figure 9.3(i) - Excess survivors per 100 patients by grade of A&E doctor compared to UK norm

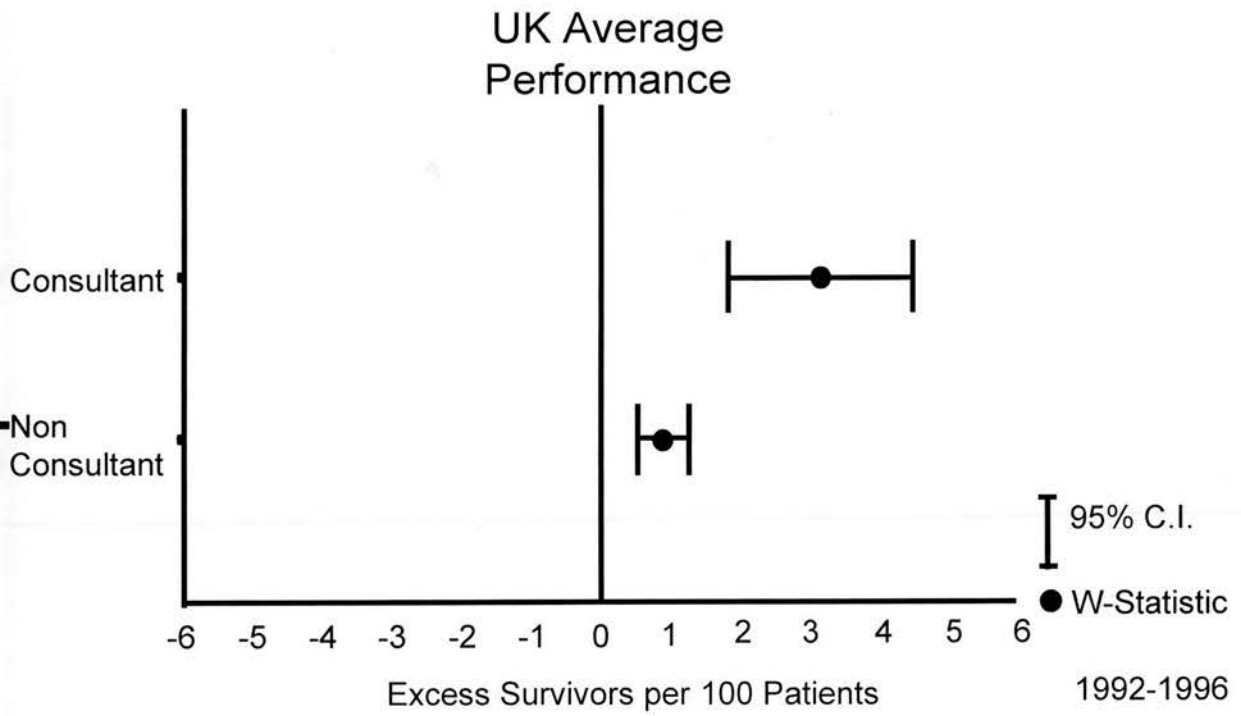


Figure 9.3(ii) - Outcome by grade of A&E doctor and time of day

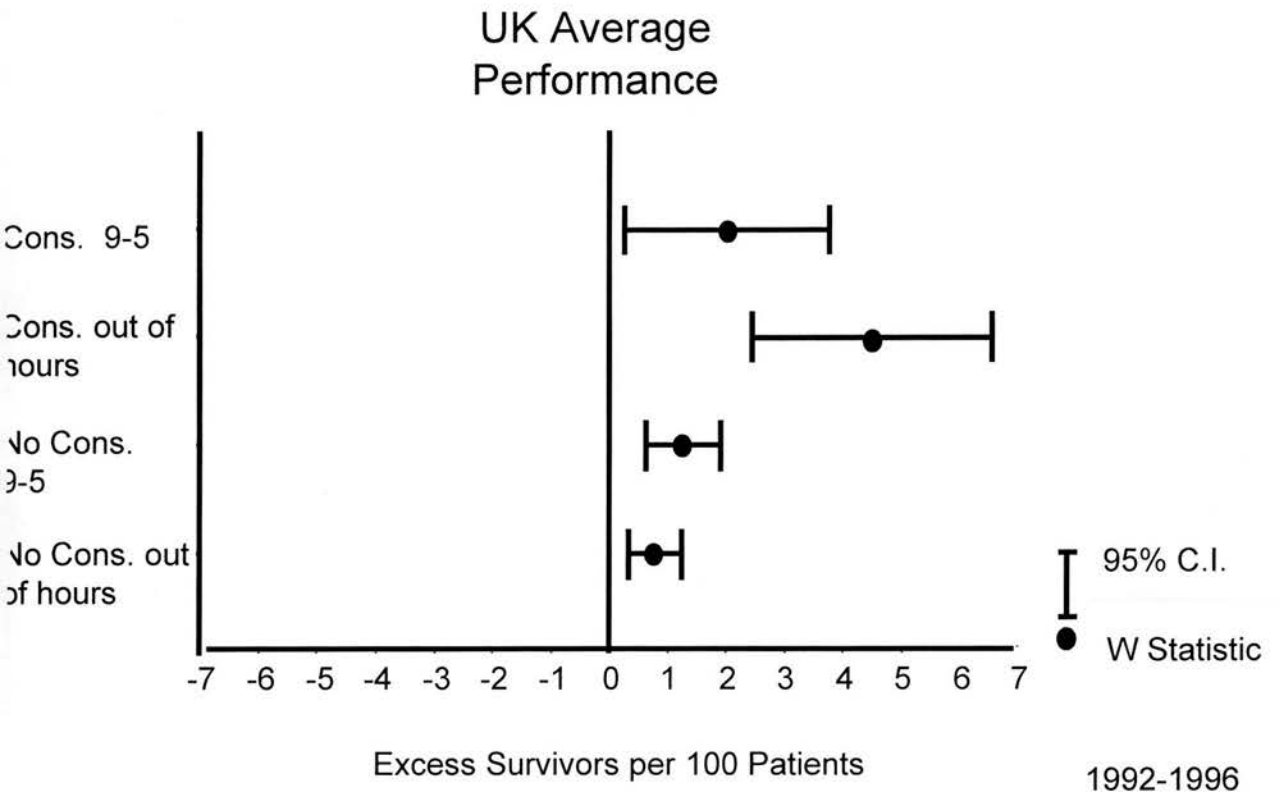
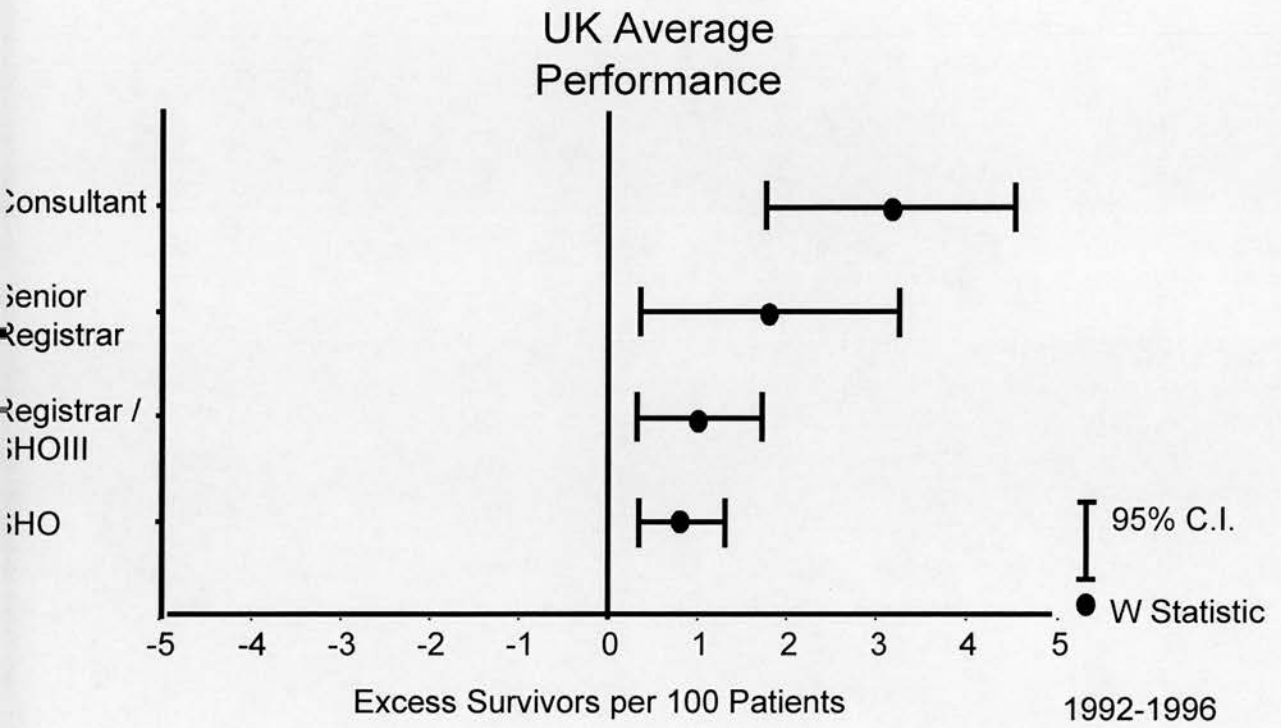


Figure 9.3(iii) - Outcome by grade of A&E doctor



Discussion

The organisation of trauma services in the UK remains controversial (O'Kelly & Westaby, 1990; Paterson-Brown, 1991; Wardrope, 1992; Nicholl et al., 1995; Nicholl & Turner, 1997; Yates, 1997; Wright, 1998). There have been calls for every hospital which manages seriously injured patients to install trauma teams comprising experienced doctors (Spencer, 1985; Heyes & Perez-Avila, 1991; Kazemi & Nayeem, 1997). Whilst improved outcome might be intuitively anticipated when patients with potentially life threatening emergencies are managed according to a team approach by trained and experienced doctors, proving this is not easy (Dollery & Driscoll, 1999). A randomised controlled trial of treatment by A&E consultants against junior doctors would not be feasible, for both logistic and ethical reasons. Similarly, a simple comparison of crude mortality rates of patients treated by consultants with those of patients treated by junior doctors would be misleading, since it takes no account of type and severity of injury, physiological derangement and age of the patient. TRISS methodology was developed using multivariate statistical techniques which take account of confounding factors, although there is some evidence to suggest that not enough account is made of the effect of old age and associated disease (Boyd et al., 1987; Pickering et al., 1999). As outlined in chapter 2, it is validated and widely used and offers an opportunity to compare the management of different groups of injured patients (Boyd et al., 1987; Champion et al., 1990; Yates et al., 1992; Wyatt et al., 1998a).

The results of this study demonstrate that treatment of injured patients is associated with a better outcome when A&E consultants are involved in the initial management, rather than junior staff. Interestingly, the data supports the concept that the training programme of junior doctors results in a gradual improvement in terms of patient care, as shown by the step-wise increase in outcome by grade of doctor.

The most obvious way in which consultants might improve outcome is by more accurate diagnosis and rapid treatment. In support of this view, it has been shown that persistent unrecognised (and thus untreated) hypoperfusion is associated with an increased mortality rate in patients with major trauma, largely as a result of "late" deaths from infection and multi-organ failure (Claridge et al., 2000). However, there are a number of other ways in which consultants might improve outcome. These include: greater early involvement of other senior specialists, more rapid transit time in A&E, more liberal use of sophisticated investigations and greater involvement of critical care areas (Parke et al., 1998). Teasing out the relative contributions of each of these factors, if any, would be extremely difficult. The results of this study do suggest that consultants are able to resuscitate and transfer patients for definitive care more rapidly than junior doctors, a finding which is in keeping with a previous study comparing the times taken to complete diagnostic tests and commence therapeutic intervention in in-house trauma surgeons with those on call (Luchette et al., 1997). Considering the relatively small number of A&E consultants, it is not surprising that the group of patients treated by a consultant

comprised a higher proportion presenting to hospital during normal working hours. However, it is interesting that the association of consultant presence with improved outcome is greatest outside “normal working hours”. The data presented supports the call for A&E consultants to be increasingly involved in the early management of major trauma. This increased involvement will necessarily include increased consultant presence outside “normal working hours”. This will only be feasible if the proposed expansion of the consultant grade in A&E medicine is extended and then actually put into practice (Audit Commission National Report, 1996).

9.4 Conclusions

The greatest potential to reduce the trauma death rate in Scotland clearly lies with injury prevention. However, data from this thesis suggest that there may be potential to “save lives” by improving hospital treatment. Although difficult, it is possible improve the management (and thereby the outcome) of the multiply injured and to demonstrate that this has occurred (Ruchholtz et al., 1998). There is evidence to suggest that there have been recent improvements in UK trauma care. Data from STAG between 1992 and 2000 shows that most Scottish hospitals have improved their W-statistic during this time. Similarly, data from England and Wales indicate a general improvement in trauma care over the past ten years (Burdett-Smith, 1995; Roberts et al., 1996; Woodford et al., 2000). Recent improvements in hospital care may be partly responsible for recent reductions in the death rates for “accidents” seen in children, young adults and the elderly (National Audit Office, 1996).

The data presented in chapter 9.3 suggest that the seniority of A&E doctor may be a factor in determining outcome following trauma (Wyatt et al., 1999e). It is therefore possible that the recent increase in numbers of A&E consultants may have contributed to recent improvements in UK trauma care. The need for every hospital which receives injured patients to have rapid access to a trauma team led by an experienced team leader has been acknowledged (Health Services Accreditation, 1997; Cooke et al., 1998). However, since future increases in A&E consultant numbers are likely to be relatively modest, it will not be feasible for them to personally see and

treat the majority of patients with moderate or severe injuries (British Association for A&E Medicine, 1998). Taking into account the future predictions of A&E consultant numbers, the continuing controversy about possible trauma centres (O'Kelly & Westaby, 1990; Wardrope, 1992; Nicholl et al., 1995; Nicholl & Turner, 1997; Yates, 1997; Wright, 1998) and the limited plans to rationalise the number and organisation of hospitals receiving trauma (Audit Commission, 1996), it seems that A&E in the UK will remain a predominantly consultant-led (rather than consultant-based) service (Binchy, 1999). In order to improve outcome following trauma it is clear that A&E consultants need to identify and target the most at-risk patients for their personal attention, and ensure that a system is in place to provide optimum care for the injured when they are not involved.

Although there is a natural tendency to focus upon the initial A&E treatment, it must be remembered that outcome following trauma depends upon the overall system of care, with input from specialists from a variety of backgrounds. These include A&E, anaesthesia, intensive care, general, thoracic, vascular, plastic and orthopaedic surgery, physiotherapy and rehabilitation. The extent to which aggressive management can potentially alter outcome is apparent, for example, in the field of orthopaedic surgery, where it has been recognised for many years that early fixation of long bone fractures is associated with improved outcome, when compared with more traditional treatment regimes (Meek et al., 1986). However, the ability of a particular hospital to deliver an aggressive (early fixation) approach to the management of fractures will depend upon several factors, including the number and

commitment of orthopaedic surgeons, as well as upon the availability of other hospital resources.

Another important factor affecting outcome after major trauma appears to be the extent to which patients are admitted to critical care areas. Increasing use of these areas, particularly amongst injured elderly patients has obvious financial implications, but might "save" lives (Parke et al., 1998). Although there appears to have been some recent improvements in the systems of trauma care provided by UK hospitals, data analysis using TRISS methodology suggests that there are still wide variations in trauma care between hospitals (Nichol et al., 1998; Woodford et al., 2000). Saving lives by improving trauma care in all hospitals to that of the best remains a challenge for the next few years, and in meeting this challenge continuing evaluation of clinical effectiveness (using STAG data and TRISS methodology) will be essential in order to identify deficiencies and monitor how they are addressed (Department of Health, 1997).

Improvements in trauma care should aim to not only result in fewer hospital deaths, but should also result in less long-term disability amongst survivors. Unfortunately, despite recognition of the need to compare expected outcome with actual outcome in terms of long-term disability as well as mortality, there is no generally accepted validated tool to measure morbidity outcomes which can rival TRISS methodology to measure mortality outcomes (Swiontkowski & Chapman, 1995). Given the magnitude of the problem of long-term disability which follows

trauma (particularly in the form of head injury and skeletal trauma), this area needs to be addressed.

computer



Chapter 10 - Conclusions

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10.1 Summary of key findings and conclusions

Personal lessons

- The direct personal experience of a doctor sustaining multiple injuries in a road traffic collision can permanently affect attitudes and alter the path of a career.
- Multiple injuries in the form of skeletal trauma and in the absence of a significant head injury can result in a good functional outcome.

The timing of death

- The vast majority of traumatic deaths in south-east Scotland involved individuals who were dead before reaching hospital. Most had either sustained unsurvivable injuries or were dead when found.
- The vast majority of children who died following trauma in south-east Scotland were dead before reaching hospital and most had either unsurvivable injuries or were dead when found.
- The findings in south-east Scotland were mirrored elsewhere in Scotland.
- There was no evidence of a classical trimodal temporal distribution of death following trauma.
- Only 15 of 1305 trauma deaths (1%) in Scotland in 1995 occurred whilst the patient was in transit by ambulance to hospital. This study did not reveal evidence of clear opportunities for improved prehospital care to prevent deaths.

Analysis of deaths amongst adults in south-east Scotland

- Analysis of suicidal deaths resulting from high falls in south-east Scotland revealed a high proportion of unsurvivable injuries and emphasised the previously noted association between a violent method of suicide and prior serious psychiatric illness. In keeping with findings from studies of suicide elsewhere, the suicidal events appeared to be difficult to predict and thus prevent. The most injured body region amongst the suicidal high falls was the chest, with complete rupture of the thoracic aorta being the most commonly seen unsurvivable injury according to the AIS.
- Fatal falls down stairs occurred most frequently amongst the elderly and amongst those who had consumed alcohol. 83% of fatal falls down stairs occurred in the deceased's own home. The proportion of those who died from unsurvivable injuries (AIS = 6) was relatively low (4 out of 51). In addition, a few individuals (4 out of 51) died with relatively less severe injuries (ISS < 15), but all were found dead, so it is not possible to imply that there is potential to save lives by improved hospital treatment. The pattern and severity of injuries amongst those who died following falls down stairs revealed that injuries to the head and/or neck were responsible for the greatest proportion of most severe injuries.
- Only 15 out of 95 (16%) deaths from drowning occurred within the bathtub, but the vast majority (84%) all took place outside in open water. Analysis revealed a failure by the public and the emergency services to both start, and also to

continue active resuscitation in accordance with standard guidelines, implying potential to save lives by improved prehospital resuscitation.

- The majority of those who died following stabbings were male and most were stabbed in the chest. Only 5 out of 20 (25%) of those who died after being stabbed reached hospital alive and all had Ps of 4% or less according to TRISS methodology, implying that improved hospital treatment has little to offer in terms of reducing the death rate. The need for prevention having been highlighted, the available evidence suggests that there may be some potential to reduce stabbings by restricting availability of weapons on the streets.
- Death following plastic bag asphyxia appeared to be relatively uncommon and in contrast to previous studies elsewhere, involved more males than females. The vast majority (27 out of 30) of plastic bag asphyxia deaths appeared to be suicides, but only four of these were known to have any contact with "self-deliverance" organisations or their literature. This contrasts with the publicity given to "self-deliverance" by the media. The fact that auto-erotic plastic bag asphyxia deaths occurred in only two individuals underlines how rare such events are. The rarity of such deaths, combined with the secrecy of the individuals who pursue autoerotic behaviour renders prevention of these deaths very difficult.
- The vast majority of motorcycling deaths (47 out of 59) occurred at scene or before reaching hospital, with 25 (42%) of those who died having sustained unsurvivable injuries, mainly involving the head, neck or chest. Efforts to reduce the number of motorcycling deaths need to continue to focus on injury

prevention, both by introducing measures aimed at preventing motorcycling collisions and by measures aimed at reducing the severity of injuries sustained in the event of a collision.

- Compared with other traumatic causes of death, pedestrian deaths after collisions with a motor vehicle were relatively common (145 deaths in seven years, at a rate of 2.5 per 100,000 population per year). Deaths amongst pedestrians differed from those from other mechanisms in two important respects: firstly, most of the pedestrian deaths involved people aged over 60 years and secondly, most actually reached hospital alive. The group of pedestrians (a large proportion of whom are elderly) who survive to reach hospital may be worthy of targeting for additional resources. Despite the fact that most of the collisions appeared to have been a direct consequence of the actions of the pedestrians (many of whom were physically incapacitated or under the influence of alcohol), analysis of the circumstances suggested that it may be more effective to target measures aimed at altering the behaviour of the drivers rather than the pedestrians.

Analysis of deaths amongst children in south-east Scotland

- Deaths from hanging amongst children accounted for 8.4% of paediatric trauma deaths (12 out of 143) and represented the fourth most common cause of death after trauma in children. Six of the twelve deaths appeared to be suicides, the other six unintentional events. Unlike the situation seen in adults where incomplete suspension is typically seen, six of the children (50%) were completely suspended. The ligatures used in the hangings comprised a variety of objects in everyday use and which may be found in many homes, rendering prevention by limiting access to potential ligatures problematic. A broad classification of paediatric hanging deaths based upon the age of the child and the circumstances is proposed.
- Road traffic collisions were the leading cause of traumatic death in children accounting for a large number of deaths (89 in children aged less than 15 years over a 14 year period). The vast majority were either pedestrians (49%) or passengers in cars (37%), with the remainder being pedal cyclists. Two-thirds of fatally injured children (59 out of 89) failed to reach hospital alive, 23 of whom had unsurvivable injuries (AIS = 6, ISS = 75), underlining the importance of injury prevention rather than improved hospital treatment. Analysis of the circumstances revealed that most of the pedestrians and cyclists who died had collisions which were a direct consequence of their own actions. The results suggest that road traffic collision deaths amongst children might be prevented by the following: increasing supervision of younger children, altering the behaviour

of other (adult) road users to render the roads safer for children and improving the use and efficacy of various secondary prevention measures (such as cycle helmets, seat belts, "pedestrian-friendly" car bonnets).

Analysis of deaths in south-east Scotland according to mechanism of injury

- Forty-nine out of 52 thoracic aortic injuries followed blunt (rather than penetrating) injury, with 46 (88%) sustaining injuries in road traffic collisions or in high falls. Only nine patients (17%) reached hospital with signs of life, and all but two died. Of the 349 deaths from all causes of trauma in two years in south-east Scotland, 50 (14%) had sustained a thoracic aortic injury. Thoracic aortic injury should be suspected in patients presenting to hospital following high energy impacts. The approach of performing an analysis according to the finding of a specific pathological injury appears to have limited potential in terms of the identification of ways of reducing deaths.

"Accidents" or injuries - epidemiology and prevention

- Review of the definition and use of the word "accident" within the English language revealed phrases which indicate deep-rooted cultural beliefs regarding the random occurrence, yet inevitability of injurious events.

- Prospective study of deaths following trauma throughout Scotland in 1995 revealed 1305 deaths (977 males, 328 females) following trauma, of which 105 appeared to be homicides, 324 suicides and of 876 unintentional origin. In keeping with data from south-east Scotland, road traffic collisions were the leading cause of traumatic death, accounting for 406 (31%) deaths. Analysis of the circumstances of the 1305 deaths challenges the view of traumatic deaths as being unpreventable, chance events. Alcohol was the factor which was implicated most frequently (417 out of 1305 deaths (32%)), either involving the deceased and/or another individual in the fatal injury sequence. The extent to which alcohol was implicated varied between different mechanisms of injury, but was greatest for fire deaths, road traffic collision pedestrian deaths and falls down stairs. Given the role of alcohol within society, the prevention of alcohol-associated trauma deaths presents a considerable challenge.

The role of prehospital trauma care

- Anecdotal evidence, in the form of a positive outcome after treatment of a limited number of individuals in the prehospital setting, may be viewed as powerful evidence by those involved in prehospital care, but lacks scientific value and is not proven on scientific scrutiny.
- Similarly, from the limited analysis of the results of the performance of the hospital-based flying squad in the Royal Infirmary of Edinburgh presented it is

difficult to reach definite objective conclusions about the value of the flying squad, in terms of improving patient outcome, whether for trauma or for other conditions. Subjectively, it did appear that the flying squad offered valuable training for hospital staff and allowed them to develop relationships with members of the other emergency services.

- Review of the evidence for the benefits of advanced prehospital care failed to allow definite conclusions to be reached, so this area remains highly controversial.

The potential for improved hospital care to prevent deaths

- Analysis of the results of the performance of Scottish hospitals in the management of trauma using TRISS methodology indicated that there appears to have been a general improvement over time. TRISS methodology indicated that there was a wide variation between Scottish hospitals in terms of the outcome of patients after trauma. Calculations using TRISS methodology suggested that if the trauma care in all Scottish hospitals had matched that of the best performing hospital, there would have been 1241 deaths, not 1305 (i.e. 64 fewer deaths) in 1995. This finding confirmed that from the studies on the timing of death in that it demonstrated that the potential to save lives by improving hospital care is dwarfed by that of injury prevention.
- Data from four Scottish teaching hospitals revealed that the involvement of A&E consultants in the initial management of trauma was associated with a

significantly better ($p < 0.05$) outcome, when compared with the outcome of those patients managed by junior doctors. The data suggested a step-wise improvement in outcome according to the grade of A&E doctor, and also suggested that the impact of a consultant was greater out of hours rather than during normal working hours. The results support the call for greater involvement of A&E consultants in the initial management of major trauma, although from a logistic point of view this could only be achieved if more resources were made available.

10.2 Future work and direction

Unfortunately, the data within this thesis serve to emphasise just how much work remains to be done in terms of reducing deaths following trauma in Scotland.

The aims most worthy of consideration in descending order of importance are:

- (i) to prevent injurious events
- (ii) to reduce the severity of injuries sustained as a result of injurious events
- (iii) to improve prehospital and hospital treatment

The prevention of injurious events

Despite numerous studies, much work remains to be done in helping to ascertain exactly how injurious events occur and hence how they might be most easily prevented. This work needs to continue at a variety of different levels, in order to understand the interaction between psychological, behavioural, social, legal and technological factors. The potential for effective injury prevention measures to reduce the number of trauma deaths needs to be acknowledged, enabling future work to be adequately funded.

Reducing the severity of injuries sustained

"Secondary prevention" measures, such as seat belts, air bags and cycle helmets, are well established. Further analysis of the pattern of injuries resulting from specific mechanisms of injury may enable the development of both simple and technologically complex ways of reducing injuries.

Improving prehospital and hospital care

Investigation into the role of prehospital care needs to continue in a dispassionate and objective fashion. Once firm conclusions can be reached regarding the role of advanced prehospital care, they should be acted upon accordingly, perhaps involving a redistribution of resources.

Efforts to improve hospital care need to be applauded and encouraged. Systems of care which are associated with better outcomes need to be analysed to ascertain which factors are responsible. These systems of care need to act as models for care occurring elsewhere in order to help to improve outcome.

The problems associated with paediatric injury scoring and the prediction of outcome amongst hospitalised injured children need to be addressed. Objective methods of analysing the care of injured children need to be developed further and implemented in order to ascertain how paediatric trauma care can improve.

Finally, it needs to be recognised that objective analysis of the management of trauma using survival or death as the sole measure of outcome is a relatively crude tool. Alternative methods need to be developed which also take the extent of long-term disability into account and enable discrimination between various treatment regimes on this basis.

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Details of published abstracts

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In Press: Journal of Clinical Forensic Medicine.

Appendix: Copies of papers arising from this work

Copies of the published papers which follow are included within this thesis with the permission of the relevant journals.

PERSONAL VIEW

My accident was my fault

Jonathan P Wyatt

My accident was my fault. I sustained multiple injuries. Dozing off to sleep I jerked awake to discover the bright lights of a 50 ton lorry looming and felt certain I was about to die. An enormous, painful bang followed. With great surprise I found I was alive. Alive and awake and no head injury. The air was filled with a choking smell of burning rubber. I checked that all limbs were attached then felt pain in my legs.

My van was a mess. There was no question of trying to get out. The hiss and smell of petrol from the engine on my lap alarmed me. The lorry driver, thankfully unhurt, appeared shouting a justified torrent of abuse. He relented when I apologised and explained my predicament. I asked him to get his fire extinguisher: he helped further by radioing for help.

Other vehicles arrived—the first few did not stop but weaved awkwardly past and carried on. My early thoughts were quite inappropriate. I recall annoyance at missing excellent ice climbing conditions forecast for the following weekend. Rather dispassionately, I surveyed the damage. My thighs were aching—clearly both femurs were broken. Unfortunately, my seat had buckled so my legs were hanging free, pulling the fractures apart. I found I could help by pulling upwards under my knees. This caused discomfort in my wrist, but I failed to recognise the fracture there. In fact, my clinical assessment was disappointing—I diagnosed only two out of eight fractures. I was unable to use the drip which I carried as it was out of reach under my seat. As my wait continued I became aware of right sided pleuritic chest pain and dyspnoea. I could not detect subcutaneous emphysema or tracheal deviation but was worried about a pneumothorax.

By now dozens of people were milling around. Police arrived and took full details from me. I asked them to send for the "flying squad" from the teaching hospital 45 km away, where I had previously worked. An ambulance arrived, but it did not carry drip sets. The ambulance crew explained that once freed I would be taken to the local district general hospital. I told them I wanted to go to the larger teaching hospital which

was more skilled in major trauma. I was told it was "outside their area" and an argument ensued. Thankfully, a policeman intervened saying he would contact a different ambulance crew. A fire engine arrived, but without the appropriate cutting equipment. Another one was sent for.

I became thirsty and cold. Things seemed chaotic. I asked again for someone to call for the flying squad, but it did not come. I discovered later that my requests never got through.

"I worry that non-medical professionals are making important decisions about the transfer of seriously ill patients."

People wandered about, some smoking, despite the petrol. A second ambulance appeared, this one prepared to take me where I wanted. The first ambulance departed, its driver understandably irritated. Eventually, more fire fighters arrived and cut me out. They lifted me slowly, but I experienced severe pain as various fractures jostled for position. My contorted legs would not fit into splints so they were simply supported with pillows.

Once in the ambulance I expected a rapid transfer to hospital. I was surprised to be delayed by a new policeman who insisted on asking the same questions I had previously answered. Apparently, the earlier policeman had gone off duty. I explained, admittedly somewhat profanely, that I thought I had a potentially life threatening combination of severe blood loss and a punctured lung, but it was to no avail. I was furious, but realised the easiest thing would be to answer his questions, which included such gems as, "Where were you born?" This surrealistic experience continued languidly as I spelt out Old Coulsdon and then had to explain where it was. My transfer was delayed for about ten minutes.

Eventually, the ambulance started moving. I felt every bump through my femurs, but declined nitrous oxide-oxygen feeling that I wanted to remain alert and in control. Although I knew it was ridiculous, my thirst became overpowering and I found myself asking for water. I got the expected and quite proper answer and was irritated with myself. I soon felt light headed and wondered if I had reached my limit of compensation for hypovolaemia. The ambulance was equipped

with extra equipment but the crew was not specially trained. I instructed one ambulance-man on how to arrange a drip set, then stopped the ambulance briefly, while I inserted a green venflon into my left cephalic vein. I did not feel the needle and was extremely relieved to see the flashback. I ran in a litre of clear fluid before reaching the relative haven of hospital.

My accident taught me some lessons. One has been learnt by others: the folly of driving 800 km after a night on call. Many doctors have been injured and some killed travelling between jobs. On 31 January and 31 July I believe this could be prevented by a change in the system of job changeovers.

I now carry a fire extinguisher in my van, although it would have a doubtful impact on a serious fire. I have administered intravenous fluid at four road traffic accidents while off duty. I recommend that all doctors carry resuscitation sets in the boots of their vehicles where they are secure and available for self administration. I believe all ambulances should be fitted with such equipment, regardless of the crew's skills, because a doctor is often available.

As a doctor I was able to alter my care in two ways: setting up a drip and changing my destination to a larger hospital. But I was unable to get a message through to the flying squad. This underlines the importance of accurate relay of information between the various components of the emergency services. Arguments concerning the role of flying squads continue but they have several advantages in certain situations. Firstly, in addition to starting resuscitation and administering analgesia to allow splintage, an experienced team could enforce sensible precautions, including the prevention of smoking near petrol. Secondly, outrageous transfer delays, such as those caused by unnecessary and inappropriate collection of useless data might be prevented. The policeman who enforced my delay undoubtedly believed that he was acting correctly. I assume that because my injuries were mostly closed he underestimated the need for urgent treatment. I worry that non-medical professionals are making important decisions about the transfer of seriously injured patients. This problem would not exist with experienced doctors at the scene.

To try to identify the scale of the problem I would be interested to hear from doctors who have suffered injuries because of fatigue at the time they change jobs.—JONATHAN P WYATT is a registrar in accident and emergency, Western Infirmary, Dumbarton Road, Glasgow G11 6NT

The time of death after trauma

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BMJ 1995;310:1502

Timing of deaths after trauma in San Francisco compared with south east Scotland

Time of death (hours after injury)	San Francisco (%)	South east Scotland (%)
<1	50	76
1-4	30	7
>4	20	17

The pre-eminence of trauma as a cause of death in young adults in the United Kingdom is well established, but little is known about the temporal distribution of these deaths.¹ The only complete data are from a frequently quoted paper, in which Trunkey described trauma deaths in San Francisco over two years.² These data are nearly two decades old and come from a country where the causes of trauma and the system for dealing with it differ from those in the United Kingdom.

Patients, methods, and results

All patients aged over 12 who died after trauma in the Lothian and Borders regions of Scotland between 1 February 1992 and 31 January 1994 were studied prospectively by the Scottish Trauma Audit Group and the university department of forensic medicine. The time and mechanism of injury and the time of death were recorded. Postmortem examinations were performed in every case, and injury severity scores calculated, using the abbreviated injury scale, 1990 revision. The definition of trauma used was that previously used by Trunkey, allowing direct comparison.

There were 331 deaths following trauma, including 26 murders and 98 suicides. Of the victims, 253 (76%) died within one hour of injury; 248 of these died instantaneously and had unsurvivable injuries (abbreviated injury scale 6, injury severity score 75) or were found dead. The remaining five patients died at the scene or in transit to hospital. Seventy eight patients survived more than one hour after injury; 59 surviving for more than four hours. The table compares the timing of deaths after trauma in this study with the United States data.

Comment

In his analysis Trunkey suggested that deaths after trauma follow a trimodal distribution.² The first and

largest peak, comprising 50% of the total, is seen immediately, or within seconds of injury. The second peak, 30% of deaths, occurs up to four hours later, while the third comprises those 20% of patients who die after four hours.

Much significance has been placed on this temporal relation, particularly to the second peak.^{2,3} Many commentators believe that appropriate intervention for patients in this group offers the greatest potential for preventing unnecessary deaths.^{2,3} As a result, the provision and nature of prehospital and hospital trauma services have been profoundly affected, both in the United States and the United Kingdom. In particular, ambulance service paramedic training and the concept of trauma centres have received considerable attention.^{4,5}

It is therefore relevant that three quarters of the patients in this study died immediately or were found dead at the scene. Furthermore, the subsequent deaths do not cluster together into the peaks previously described in north America. The accepted concept of a trimodal distribution of death after trauma does not apply in our area. This may be partly due to improvements in trauma care, resulting in fewer unnecessary deaths. Data from the Scottish trauma audit group for our region confirm that there are significantly more survivors after trauma than predicted from the United Kingdom dataset, but the numbers in this category are small and insufficient to affect the overall conclusions. A more important factor is likely to be the type of trauma seen.

If our results are mirrored throughout the United Kingdom, they necessitate a re-evaluation of pre-hospital and trauma care systems. Attempts to improve care for those who initially survive major trauma must continue, but our study emphasises that prevention offers the most cost effective and rational approach.

We thank Mr David Steedman and the Scottish Trauma Audit Group for advice and help with this study.

1 Accidents. In: *The Health of the Nation*. London: HMSO, 1992:102-15.

2 Trunkey DD. Trauma. *Sci Am* 1983;249(2):20-7.

3 Royal College of Surgeons of England. *Report of the working party on the management of patients with major injuries*. London: Royal College of Surgeons of England, 1988.

4 Anderson ID, Moodford M, deDombal FT, Irving M. Retrospective study of 1000 deaths from injury in England and Wales. *BMJ* 1988;296:1305-8.

5 The Scottish Home and Health Department. *Emergency healthcare in Scotland: future structure of accident and emergency services*. Edinburgh: HMSO, 1994.

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Rate, causes and prevention of deaths from injuries in south-east Scotland

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Data on all deaths after injuries in Lothian and Borders regions of south-east Scotland were collected prospectively over 2 years. Post-mortems were performed after all deaths and Injury Severity Scores (ISS) calculated. There were 331 deaths at a rate of 20 per 100 000 per year; of those who died 49 per cent were younger than 40 years and most were male; 37 per cent of deaths were caused by road traffic accidents, 16 per cent by falls and 15 per cent by hangings. Two hundred and forty-eight patients (75 per cent) were either dead when found or died instantly with unsurvivable injuries (ISS = 75). A further five patients died in the first hour after injury and before reaching hospital. Nineteen (7 per cent) died between 1 and 4 h after injury, 59 (17 per cent) died more than 4 h after. These results demonstrate the rate, causes and timing of deaths following injuries in one UK region. The pattern of these deaths differs markedly from that previously described in the US. There is no evidence to support the concept of a trimodal distribution of trauma deaths. The greatest potential to reduce the number of trauma deaths lies with prevention. Copyright © 1996 Published by Elsevier Science Ltd.

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Introduction

Trauma is the leading cause of death amongst young adults¹⁻³. Recognition of this, together with evidence of major shortcomings in trauma care in the UK^{4,5}, has resulted in increased interest in trauma and its management.

Data regarding the rate, causes and timing of deaths from trauma in the USA are known⁶. Trunkey described all deaths from injuries in those aged over 12 years in San Francisco during 1977-1978. Surprisingly, no similar complete data exist for UK trauma deaths. An examination of the rate, causes and timing of deaths after injuries is of central importance in order to allow rational planning of both trauma care and trauma prevention in this country. This paper describes the trauma deaths in one region of the UK during a 2-year period, with emphasis on their causation, the time and place of death and potential for intervention.

Patients and methods

Data was collected prospectively on all deaths from injuries in a 2-year period (1 February 1992 - 31 January

1994) for patients aged over 12 years in the Lothian and Borders regions of south-east Scotland. The same definition of trauma as that used previously by Trunkey was employed, allowing direct comparison with data from the USA.

Details recorded on each patient include age, sex, mechanism of injury, times of injury and death, transportation times to hospital and place of death. Post-mortem examinations were performed in every case during the study period. These examinations were performed by staff of the Forensic Medicine Unit and the Department of Pathology at the University of Edinburgh. Abbreviated Injury Scores (AIS) and the derived Injury Severity Scores (ISS)⁷ were calculated on all patients by the Scottish Trauma Audit Group.

Results

During the 2-year period, there were 331 deaths following injuries in the study area. The population studied was slightly in excess of 0.8 million⁸, giving an annual rate of death from trauma of 20 per cent 100 000; 49 per cent of those who died were aged less than 40 years. The age and sex distribution of the patients are shown in *Figure 1*.

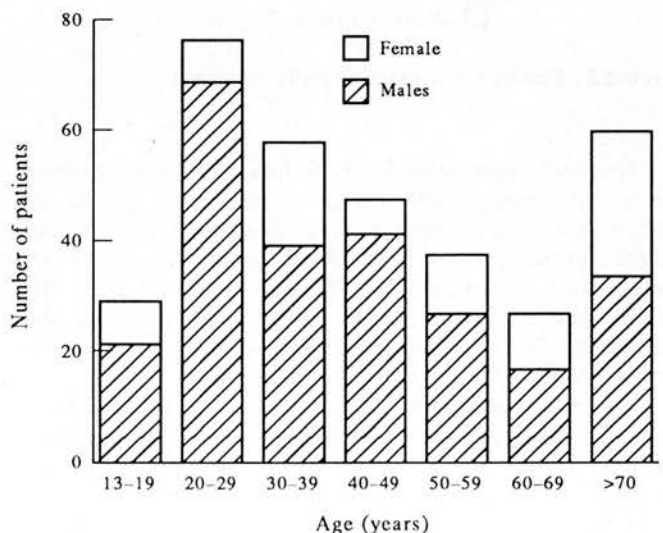
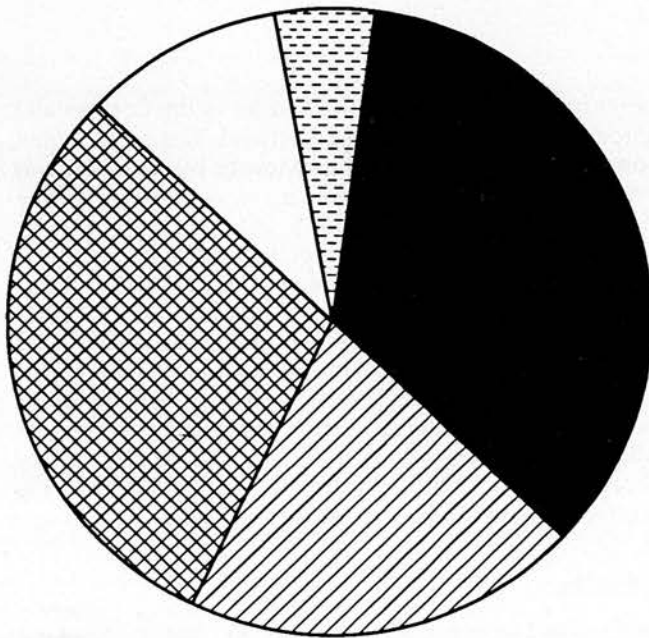


Figure 1. Age and sex distribution.

Table I. Aetiology of trauma

Mechanism	Homicide	Suicide	Accident	Total (%)
Road accident	0	3	121	124 (37%)
Fall	1	16	35	52 (16%)
Hanging	0	51	0	51 (15%)
Drowning	0	11	12	23 (7%)
Assault	21	0	0	21 (6%)
Burns/smoke inhalation	0	1	19	20 (6%)
Hit by train	0	3	5	8 (2%)
Electrocution	0	3	2	5 (2%)
Suffocation	2	1	2	5 (2%)
Other	0	11	11	22 (7%)
Total	26	98	207	331

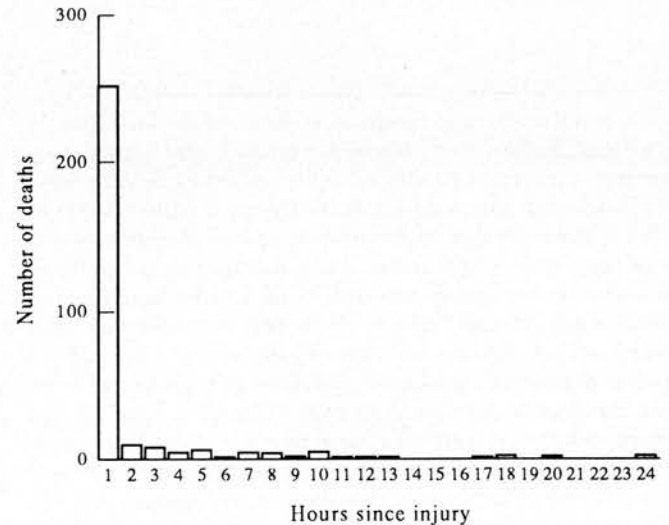


- Car drivers (mean 34 yrs)
- ▨ Car passengers (mean 38 yrs)
- ▩ Pedestrians (mean 62 yrs)
- Motorcyclists (mean 30 yrs)
- ▤ Bicyclists (mean 26 yrs)

Figure 2. Deaths following road traffic accidents.

The vast majority of deaths following injuries resulted from blunt injury (309 deaths (93 per cent)). Of the 22 penetrating injuries, nine involved firearms (one homicide, eight suicides) and 13 involved knives (including 11 homicides). Amongst the 331 deaths, there were 26 homicides (8 per cent) and 98 suicides (30 per cent). The remaining 207 deaths (62 per cent) are believed to have been 'accidental'.

Table I demonstrates that road traffic accidents (RTAs) were the leading cause of death. These comprised a large number of young car occupants and older pedestrians (Figure 2). Fifty-two deaths were caused by falls, with 35 patients (67 per cent) falling more than 2 m. Twelve deaths (4 per cent) occurred at the workplace: these included seven crush injuries.

**Figure 3.** Timing of deaths within the first 24 h.**Table II.** The five non-instantaneous pre-hospital deaths

No.	Age (years)	Sex	Mechanism	Time to death (min)	ISS
1	27	M	Drowning	42	NSI
2	18	M	Car driver	35	34
3	23	M	Car passenger	45	33
4	43	M	Pedestrian	35	34
5	19	M	Car driver	61	16

NSI = Non-scorable injury.

Two hundred and ninety-eight deaths (90 per cent) occurred within 24 h of injury. The temporal distribution of these deaths is shown in Figure 3. Two hundred and forty-eight patients died instantaneously and had injuries acknowledged to be unsurvivable (AIS 6, ISS = 75), or were dead when first found.

A further five patients died within an hour of injury. All of these patients died before reaching hospital, either at the scene or in transit. The age, sex and injuries of each of these five patients is shown in Table II. None appeared to have died from airway obstruction which would have been amenable to first aid measures from bystanders with no equipment.

Seventy-eight patients showed signs of life at some stage and received treatment from the emergency and

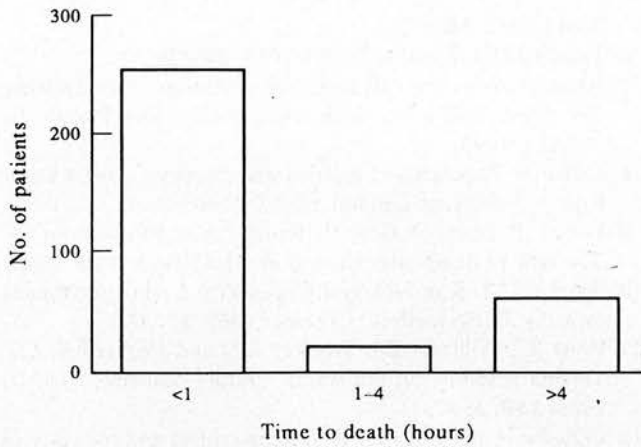


Figure 4. Time to death after injury.

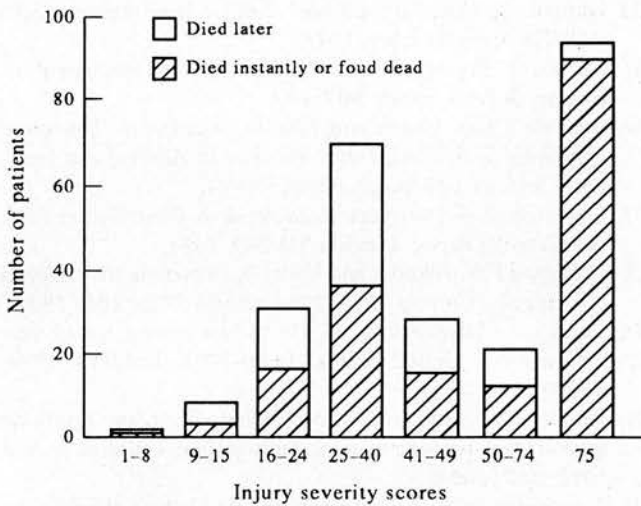


Figure 5. ISS of the 248 patients with scorable injuries.

subsequently hospital services. Nineteen patients (7 per cent) died between 1 and 4 h after their injuries, 59 patients (17 per cent) died after more than 4 h (Figure 4)⁹.

Eighty-three patients had injuries which were 'not scorable' – these included those patients found dead after hangings or drownings. The remaining 248 patients had injuries which were scored to produce an ISS, shown in Figure 5, according to the timing of death.

During the study period, 2150 patients treated for injuries in south-east Scotland were entered into the Scottish Trauma Audit Group database. This data has been independently analysed and validated by the Major Trauma Outcome Study (UK)¹⁰ and indicates that this centre performed statistically significantly better than the UK norm, with 1.86 'excess' survivors per 100 patients (*W* statistic 1.86, *Z* statistic 4.83) (MTOS UK, personal communication).

Discussion

Death and injury following trauma are emotive subjects. Considerable debate has taken place amongst doctors, the general public and politicians as to what constitute the best mechanisms to deliver appropriate levels of care¹¹⁻¹⁶. Some trauma statistics, such as death and injury following RTAs, are carefully and reliably collated in this country¹⁷.

There is, however, a surprising paucity of information on the global aspects of trauma and particularly, on the timing of death and the potential for successful medical intervention.

This study is believed to be the first in the UK to incorporate the contributions made by both in-hospital and out-of-hospital deaths, where post-mortem information is available for every death. This has been facilitated by the unique method of data collection in Scotland where law officers in the Crown Office work closely with the medical staff in the Forensic Medicine Unit.

The results of this study confirm that trauma plays a significant part in premature death in the UK, especially amongst young males. Road traffic accidents account for the greatest number of these. This is in keeping with previous data from this country, other parts of Europe and the USA^{2,3,17}. The 1993 financial costs associated with RTAs have been estimated at £744 000 per death and £84 000 for individuals sustaining serious injury¹⁷. The overall annual cost to the Exchequer from such deaths in the UK is therefore enormous.

Although RTAs also account for a considerable number of deaths in the USA, there were marked differences in the patterns of death following trauma. Cultural and geographical differences may be partly responsible for this. For example, deaths from drowning in the USA are not only seen in marine and freshwater environments, but also in the context of increased accessibility to home swimming pools¹⁸. By contrast, despite a coastline in this study of 160 km, there were only 23 deaths from drowning and none occurred in a home swimming pool.

The USA experiences a far greater proportion of penetrating injuries^{2,19}. This is demonstrated by deaths from violence, which show marked differences in both aetiology and incidence². The total number of homicides in south-east Scotland in the 2 years of this study for a population of 0.8 million is similar to that seen in a single day amongst the same-sized population in many American cities²⁰. In keeping with previous data from other parts of the UK, the majority of homicides in this study resulted from blunt injury or penetrating injury caused by knives, rather than the firearms commonly used in the USA^{2,19}. There was only one homicide involving firearms, although eight individuals used them to commit suicide, possibly reflecting the ready access to this mode of death within rural or farming communities.

Following Trunkey's paper on trauma deaths in San Francisco, the concept of a trimodal distribution of such deaths has become accepted⁶. The first peak of deaths (50 per cent) occurs soon after trauma and represents overwhelming injury. The second peak of deaths (30 per cent) includes those patients who die up to 4 h after trauma, the third peak (20 per cent) those who die after 4 h. It is believed by some that great potential for reducing deaths from trauma exists by improving treatment to diminish the second and third peaks^{4,21,22}. This belief has moulded trauma care services in both the USA and the UK, with development of paramedic services and trauma centres^{4,12,16}. This study demonstrates that a trimodal distribution of trauma deaths does not exist in south-east Scotland. These results have significant implications for the provision of trauma services in the UK. It may be tempting to attribute the lack of demonstrable second and third peaks of trauma deaths in south east Scotland to high-quality treatment. There is certainly evidence to support this view. However, it seems much more likely that the

results reflect the previously mentioned differences in patterns of trauma seen in the UK when compared with the USA. Further studies should resolve this.

The role of basic life-saving techniques by members of the lay public in saving a significant number of pre-hospital deaths from trauma has recently been proposed²³. The results of this study provide no evidence to support this view. Previous estimates of the potential for basic life-saving techniques have emphasized the limitations of even paramedic interventions, although on-scene care provided by hospital-based accident flying squads or specifically trained general practitioners has been shown to provide beneficial outcomes^{24,25}.

The temporal distribution of trauma deaths in this study indicates that the potential for 'saving lives' from trauma in south-east Scotland by improving treatment is currently significantly less than that suggested by previous work^{1,4}. Heightened awareness already exists for the need for victims of major trauma to be treated promptly and efficiently by properly trained, experienced personnel. This necessitates rapid delivery and concentration of severely injured patients to centres which can provide senior experienced personnel of the relevant disciplines, together with the appropriate diagnostic and therapeutic facilities on a 24-h basis¹⁶.

It is clear that the greatest potential for reducing deaths from injuries lies with prevention. Preventative measures may be largely responsible for the steady decline in the number and severity of RTAs, despite increased road usage¹⁷. These preventative measures may include public education, legislation, developments in road-safety engineering and technological advances in motor vehicle design^{2,26,27}. Prevention of occupational injuries and deaths should remain a priority for those involved in producing and enforcing legislation for the workplace. For the prevention of some traumatic deaths, including homicides and suicides, the way forward is less clear²⁸. However, the size and nature of the problem demands that preventative efforts must continue.

Acknowledgements

Thanks are extended to Mr David Steedman and the Scottish Trauma Audit Group for advice and help with this study.

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CASE REPORT

Survival after laceration of the superior vena cava from blunt chest trauma

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Laceration of the superior vena cava is an unusual result of blunt trauma and is almost invariably lethal. A case caused by a high speed road traffic accident is presented; the factors relating to survival are discussed.

Keywords: superior vena cava; laceration; blunt chest injuries; major trauma; prehospital care; accident flying squad

CASE REPORT

A 30-year-old female car driver collided with the rear of a stationary bus, at an estimated speed of 60-70 miles per hour. She was wearing a seat belt at the time of the accident but the car was not fitted with an air bag.

The impact produced considerable intrusion into the driver's compartment, entrapping the driver. The emergency services on scene had therefore requested the assistance of the hospital-based mobile medical team.

On arrival of the mobile medical team (MEDIC 1) (Dark *et al.*, 1990), her pulse rate was 140/minute, her blood pressure was unrecordable, her respiratory rate was 8/minute and she was deeply unconscious [Glasgow Coma Scale (GCS) 4/15 (E1 M2 V1)]. Her pupils were 4 mm diameter, equal, non-reactive and divergent. She was already receiving oxygen by face mask and a hard cervical collar had been applied. Deformation of the vehicle caused her to be trapped upright in the driver's seat by the lower limbs. Initial examination revealed a compound fracture of the right mandible with loose teeth and blood partially obstructing her upper airway. There was palpable

left-sided chest wall crepitus, but bilateral air entry on auscultation. There were compound fractures of the right elbow and both femoral shafts.

Two large bore i.v. lines were inserted and rapid i.v. volume replacement with crystalloid and colloid solutions was commenced. Rapid extrication from the vehicle was achieved with the help of the Fire Service. In view of worsening airway obstruction, major chest injury and hypoventilation, a rapid sequence induction was performed at scene. Endotracheal intubation was performed with in-line cervical immobilization. After splinting her lower limbs, she was transferred to the accident and emergency department.

Infusion of further intravenous fluids, including Group O Rhesus negative blood, was continued in the resuscitation room to treat continuing clinical evidence of hypovolaemia. In view of the mechanical ventilation following thoracic trauma and clinical suspicion of pneumothorax, bilateral chest drains were inserted. A right femoral arterial line was inserted. Bilateral traction splints were applied to the lower limbs.

Chest X-ray showed a wide mediastinum with bilateral pulmonary contusions and fragments of teeth in the lower oesophagus (Fig. 1). Pelvic X-ray failed to reveal new bony injury. Repeat chest X-rays demonstrated progressively increasing

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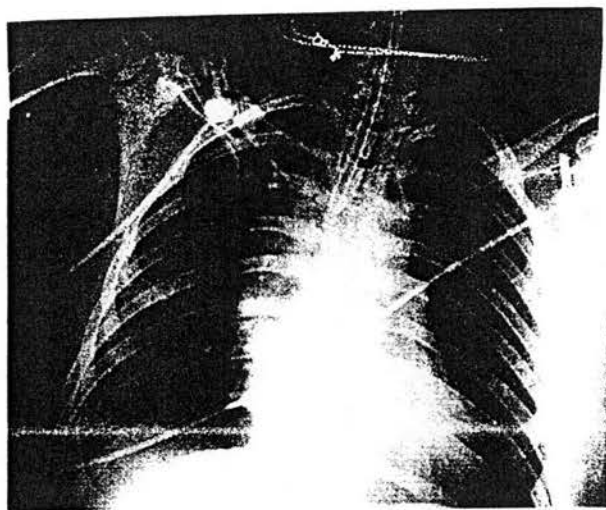


Fig. 1. Chest X-ray on admission to accident and emergency department.



Fig. 2. Chest X-ray 25 min after admission.

width of the mediastinum and deviation of the nasogastric tube to the right (Fig. 2). A supra-clavicular subclavian central line was inserted and although distended neck veins were noted at that time, a formal central venous pressure (CVP) measurement was not made. The patient was considered too unstable for further diagnostic imaging studies. Preparations were made for emergency surgery with cardiopulmonary bypass. She was transferred to the cardiothoracic theatre after 39 min in the resuscitation room.

Thoracotomy was performed via median sternotomy revealing cardiac tamponade. This was surgically released with an immediate and dramatic improvement in her haemodynamic state. Further

examination of the mediastinum demonstrated a laceration of the superior vena cava (SVC) at the junction of SVC and an aberrant right mammary vein just superior to the pericardium. There was a large amount of haematoma related to the right wall of the pericardium with a defect in the pericardium at the junction of the SVC, right atrium and right upper pulmonary vein. The defect in the SVC was repaired and the haematoma was evacuated. Contusion of both lungs and fractures of several ribs on the right were also noted at operation. The thoracic aorta appeared to be intact. Laparotomy revealed two small tears in the capsule of the liver requiring no surgical intervention. A small amount of intraperitoneal blood was removed. A small retroperitoneal haematoma was noted below the caecum. Pericardial, mediastinal and subhepatic drains were placed prior to skin closure. The patient was transferred to the radiology department for further imaging.

Plain radiology of skull, cervical spine and pelvis showed no bony injury. Computed tomography (CT) scan of brain and cervical spine were normal. She was therefore transferred to trauma theatre where the compound femoral injuries were debrided. An dynamic condylar screw was used to reconstruct the left femur and an external fixator was applied to the right femur. The right elbow was debrided and dressed. She was transferred to the intensive care unit (ICU) for further care.

The following day she had spontaneous eye opening and localized noxious stimuli. She subsequently returned to theatre on Day 6 for elective tracheostomy and surgery to her LeFort III facial fractures together with fixation of her fractured mandible. She also underwent open reduction and internal fixation of her right elbow with skin grafting to cover the cutaneous deficit. She subsequently had further bone grafting procedures to both legs. On Day 11 she developed adult respiratory distress syndrome (ARDS). This progressed to an extent that oxygenation was difficult to maintain despite an FiO_2 of 1.0, high positive end expiratory pressure (PEEP) and inverse ratio ventilation. She was nursed prone for 4 days. Her lung function slowly improved and she was transferred from ICU on Day 50 to a high dependency unit, breathing spontaneously through her tracheostomy. She is now awaiting further bone grafting to her left femur. Her tracheostomy wound is healing. She is alert and orientated with no neurological deficit detectable.

DISCUSSION

Laceration of the SVC is a rare and usually lethal injury (Kudsk *et al.*, 1984). Surgery is the only

intervention that will improve mortality in cases of major intrathoracic vascular injury such as SVC laceration, and even then survival is uncommon (Kudsk *et al.*, 1984; Thurman and Roettger, 1992; Walsh and Snyder, 1992; Inoue *et al.*, 1993). The differential diagnosis in this case included traumatic dissection of the thoracic aorta, but her precarious haemodynamic state precluded any further diagnostic imaging prior to emergency surgical intervention.

Several factors are likely to have affected outcome. Perhaps the most important was the fact that she received medical care at the scene, including definitive advanced airway care, by a well-trained and experienced medical team. Given the presence of foreign material in the airway along with the major chest injury, it is debatable whether she would have survived to hospital without provision of a definitive airway and paralysis for controlled ventilation during the primary transfer. Intubation without the use of anaesthetic drugs in head injury is contraindicated as it produces a rise in intracranial pressure. Paramedics within the UK are neither able to administer sedative nor neuromuscular blocking agents. If definitive airway intervention is to be performed in such a case it requires an appropriately experienced medical team on scene.

She was met by a consultant-led resuscitation team in the accident and emergency department and senior surgical and anaesthetic consultants were involved very early in her care. This facilitated direct transfer to theatre for life saving surgery after only 39 min in the resuscitation room without delay from unnecessary investigations. The role of emergency life-saving surgery in the early management of patients with trauma is worthy of emphasis (American College of Surgeons, 1993). It certainly proved to be an important factor in the survival of this patient.

This patient was at high risk of developing ARDS given her major chest injury along with the three major long bone fractures. This was actively sought in the ICU and treated aggressively. The use of the prone position in ARDS is well documented (Ryan and Pelosi, 1996). Early internal fixation certainly allows for easier nursing care in the intensive care setting although debate remains

over whether the frequency and severity of ARDS is improved by early internal fixation in the presence of thoracic trauma (Pape *et al.*, 1993).

She sustained major multiple injuries with an ISS of 34 and an RTS of 2.1, giving her a calculated probability of survival of 13.5% (using UK national database coefficients) (Scottish Trauma Audit Group, personal communication, 1996). Her ultimate recovery will unfortunately leave her with some residual locomotor disability secondary to her extensive orthopaedic injuries.

CONCLUSION

This case demonstrates the combined beneficial effect of advanced, medically delivered pre-hospital care, immediate emergency surgery and aggressive intensive care on an unusual major intrathoracic vascular injury. It is difficult to quantify the individual impact of these factors on survival, although the immediate surgery was undoubtedly lifesaving.

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Timing of paediatric deaths after trauma

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Trauma is the leading cause of death in children aged over 1 year.^{1 2} The government has identified this problem as worthy of special attention. *The Health of the Nation* sets a target of reducing the death rate for accidents in children by at least 33% by the year 2005, to no more than 4.5 per 100 000.² The principal methods of reducing the death rate are either to improve treatment for those injured or to prevent the injuries. We examined the timing of death after injury for insight into the potential of each stratagem.

Subjects, methods, and results

The deaths of all children after injury in south east Scotland are investigated by the police and by postmortem examination under the direction of the procurator fiscal. We identified deaths following trauma in children aged less than 15 years in Lothian and Borders regions of south east Scotland during the 11 years 1985-95 from forensic medicine records and the records of the procurator fiscal. A cross check was performed against data from the registrar for deaths to confirm that the dataset was complete. The mechanism of injury and times of trauma and death were obtained from forensic medicine and the procurator fiscal's records and from police, ambulance, and hospital records. Injury severity scores were calculated for each child, using the 1990 revision of the abbreviated injury scale.³

A total of 138 children (84 boys, 54 girls) died after injury during the 11 years. The 1991 census showed 146 826 children aged less than 15 years for the region; hence the overall death rate was 8.5 per 100 000 children per year. The rate varied from year to year (9.5 (14 deaths) in 1985; 8.9 (13) in 1986; 6.1 (9) in 1987; 10.9 (16) in 1988; 7.5 (11) in 1989; 4.8 (7) in 1990; 18.4 (27) in 1991; 4.1 (6) in 1992; 7.5 (11) in 1993; 8.2 (12) in both 1994 and 1995), with no discernible trend.

The mechanisms of injury responsible, and time of death, are shown in table 1. Fifty seven of the 138 deaths (41%) occurred in preschool children (aged less

than 5 years). Twenty of these had been left unsupervised in the presence of an obvious danger (access to matches, deep water, an open road, or an unguarded drop). Ninety nine children (72%) died within one hour of injury or were dead when found; 92 of these children showed no signs of life when the ambulance crew arrived at the scene. These included 40 children who had injuries considered to be unsurvivable (injury severity score=75) and 36 other children who were found dead after an unwitnessed incident.

Comment

Children continue to die after accidents with relatively predictable causes.² In south east Scotland the death rate after trauma in children fluctuates somewhat from year to year, but the overall rate remains unacceptably high. To achieve the government target for 2005, the death rate in the region needs to be reduced by 47%.

Improving hospital treatment offers only limited potential for preventing some deaths of children in hospital after injury.⁴ Most children in this study, however, were either dead when found or died at the scene of the accident before receiving medical attention. The potential for improving survival by providing seriously injured children with earlier medical attention at the scene is difficult to quantify but seems to be limited, as most children either had unsurvivable injuries or were found dead after an unwitnessed incident. These results are in keeping with those relating to adults.⁵

As with adults, the greatest potential for reducing the number of children dying after trauma lies with introducing and implementing effective accident prevention measures. The high proportion of deaths related to road traffic accidents shows the need to concentrate efforts in this area. Research designed to identify appropriate accident prevention measures should be strongly encouraged and supported. The number of deaths from injury in children will not be reduced unless this is borne in mind and resources allocated appropriately.

We thank the Scottish Trauma Audit Group for help with this study.

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Conflict of interest: None.

Table 1 Mechanism, age, and time of death after injury in children in south east Scotland, 1985-95

	Mean age (years)	Time of death after injury (hours)			No of deaths
		< 1	1-4	> 4	
Road traffic accidents:					
Pedestrian	8.6	16	0	16	32
Car passenger	5.5	22	2	2	26
Pedal cyclist	11.7	6	0	3	9
Fall from a height	4.8	6	1	4	11
Hanging	11.5	10	0	1	11
Drowning	5.4	13	0	2	15
Fire	4.5	20	1	1	22
Other	3.6	6	1	5	12
Total	6.7	99	5	34	138

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Thoracic aortic injuries in South-East Scotland

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Summary

Objective: To determine the epidemiology of thoracic aortic injuries in South-East Scotland and to draw conclusions regarding treatment and prevention of these injuries.

Methods: Data was collected prospectively on all serious injuries and deaths in Lothian and the Borders regions during 2 years. Patients who sustained thoracic aortic injuries were identified and studied in detail. All injuries were recorded and scored according to the Abbreviated Injury Scale (AIS) 1990 revision, allowing Injury Severity Scores (ISS) to be calculated.

Results: 52 thoracic aortic injuries occurred during the study period, at a rate of 1 per 32,000 people per year. 49 aortic injuries followed blunt trauma, including 37 road traffic accidents and 9 falls. 38 patients (73%) had an ISS of 75. Only 9 patients reached hospital with signs of life: two survived to discharge.

Conclusions: Thoracic aortic injuries in South-East Scotland mostly result from high energy impacts during blunt trauma. Although these injuries were implicated in 14% of all deaths following trauma, relatively few patients survived to reach hospital, reflecting the severity of both aortic and associated non-aortic injuries. The low rate of hospital presentation means that hospital specialists struggle to gain experience managing aortic injuries. Patients will therefore be best served if an established policy for investigation and management of suspected aortic injuries is in place. Since the vast majority of deaths following thoracic aortic injuries occur at the scene of accidents, it is clear that the greatest potential to reduce the death rate lies with accident prevention measures.

Key words: Aortic injury, multiple trauma, trauma deaths.

Injury to the aorta has long been recognised to be potentially catastrophic [1-6]. Previous reports have either concentrated upon hospital presentation, investigation and management of patients with aortic trauma [7-12] or upon autopsy findings [16,17]. This study provides the first complete prospective epidemiological picture of all thoracic aortic injuries in a defined population in the United Kingdom.

Materials and methods

The Scottish Trauma Audit Group and University of Edinburgh Forensic Medicine Unit prospectively collec-

ted data on all serious injuries and death from trauma in Lothian and the Borders regions of South-East Scotland over two years (February 1992 - January 1994). The methodology of trauma data collection has previously been reported [18]. The data collected included age, sex, mechanism of trauma, details of the injuries sustained, investigations, treatment and outcome. On the instructions of the Procurator Fiscal, all traumatic deaths for the entire geographical area are autopsied by the same team according to a standardised comprehensive protocol. All injuries were recorded and scored according to the AIS 1990 revision, allowing ISS to be calculated [19].

Results

Incidence: There were 52 thoracic aortic injuries amongst the 0.83 million population of Lothian and Borders in the two year study period. The 52 patients comprised 38 males and 14 females, age range of 16-84 years, mean 40 years (Table 1).

Mechanism of injury: 49 aortic injuries followed blunt trauma and three followed penetrating knife injuries. The mechanisms of the 52 injuries are shown in Table 2.

Table 1 - Age and sex of 52 patients with aortic injuries.

Age (years)	Male	Female	Total
0-10	0	0	0
11-20	7	4	11
21-30	8	1	9
31-40	8	5	13
41-50	5	0	5
51-60	2	1	3
61-70	1	1	2
71-80	6	1	7
> 80	1	1	2
Total	38	14	52

Table 2 - Mechanism of aortic injury.

Mechanism	Number	%
Road accident - car occupant	21	40
Road accident - motorcyclist	3	6
Road accident - pedestrian	13	25
Falls (all more than 2m)	9	17
Industrial accidents	3	6
Stabbings	3	6
Total	52	100

Table 3 - Aortic injuries scored according to the AIS.

AIS	Number	%
4	9	17
5	8	16
6	35	67

AIS 4 - includes intimal tears and incomplete transections with blood loss \leq 20% by volume.
 AIS 5 - includes partial and complete transections where haemorrhage is confined to the mediastinum.
 AIS 6 - includes complete transections where haemorrhage of > 20% by volume is not confined to the mediastinum.

Nine aortic injuries were sustained in suicide attempts (falls), three were homicides (stabbings) and the remaining 40 resulted from accidents.

Severity of the aortic injuries: The injuries were subdivided into intimal tears, partial ruptures and complete transections and were scored according to the AIS (Table 3). 36 patients sustained complete transections, 35 of which were complete transections with massive haemorrhage not confined to the mediastinum. Eight patients had complete transections at multiple sites, 28 had single complete transections. 20 (71%) of these 28 single complete transections occurred at the level of the junction of the junction of the arch and descending aorta, just distal to the ligamentum arteriosum.

Other injuries: 47 patients (90%) had injuries involving other body systems. The most common associated injury was rib fracture. 16 patients (31%) had non-aortic injuries recognised to be incompatible with survival (AIS = 6, ISS = 75). ISS ranged from 16-75 (Table 4).

Outcome: 12 of the 52 patients (23%) with aortic injuries reached hospital: three of these were in cardiorespiratory arrest on presentation to hospital. Two patients survived to hospital discharge (Table 5). In the two year study period there were a total of 349 deaths following trauma in Lothian and the Borders. Therefore, 14.3% of all those who died from trauma had sustained an aortic injury.

Table 4 - ISS.

ISS	Number	%
0-15	0	0
16-24	2	4
25-35	3	6
36-74	9	17
75	38	73

Table 5 - Outcome after aortic injury.

Outcome	Number	%
Died at scene or during hospital transfer	40	77
Died in A&E	3	6
Died in theatre	7	13
Survived following surgery to discharge	2	4

Conclusion

This study has defined the incidence of thoracic aortic injuries in the Lothian and Borders regions of South-East Scotland as 1 per 32,000 people per year. The annual death rate is 1 per 33,200 people.

The great majority of thoracic aortic injuries followed blunt injury rather than penetrating injury. The small number of penetrating aortic injuries is a reflection of the combination of the relatively protected anatomical position of the aorta, together with the predominance of blunt injury over penetrating injury in the UK [18-21]. The majority of the blunt injuries causing aortic injury occurred at the "classical site" just distal to the ligamentum arteriosum. This is in keeping both with autopsy reports and with previous studies which have focused upon those patients with aortic injuries who survived to reach hospital [2,8,11,14,22,23].

The exact mechanism which causes aortic injury has been investigated by experiments on animals and cadavers [24-26]. It was previously considered that differential rates of deceleration between the aortic arch and the descending aorta resulted in the commonly observed shearing transverse rupture at the junction between the two [7,27]. Alternative mechanisms have recently been suggested. These include the "osseous pinch mechanism", in which the left clavicle, first rib and sternum act together to "pinch" the aorta against the thoracic spine as they are forced posteriorly and inferiorly [28,29]. Whichever mechanism is responsible, it is clear that aortic injuries usually result from the application of very large forces: most injuries followed high speed road traffic accidents. The fact that 67% of patients suffered complete circumferential aortic rupture with massive haemorrhage explains why the majority of the patients died at the scene. This study included all patients who sustained an aortic injury: it was not simply confined to studying tho-

se patients who reached hospital alive. As a result, the overall mortality of aortic injury was very high at 96%; this is in keeping with a recent report of blunt aortic injury from Australia [30]. This extremely high mortality is partly a reflection of the significant associated injuries in other body regions (16 patients had non-aortic injuries acknowledged to be unsurvivable). This is demonstrated in the ISS of the 52 patients.

It is interesting that the youngest person to sustain an aortic injury in this series was 16 years of age. This is consistent with published series, in which blunt aortic injuries in children are rarely described [2,8,11,15,16]. The reason for this has not been established, but it may simply reflect greater elasticity of the pediatric aorta, together with a more compliant bony thorax.

Although aortic injury caused or contributed towards the deaths of 50 (14%) of the 349 patients who died following trauma in the study population, only nine patients with aortic injuries reached hospital with signs of life. Thus, the experience of any individual in managing these patients even in large centres is likely to be limited. Considering that during the study period 216 patients presented to hospital in Lothian and the Borders following significant trauma with ISS > 15 (Personal Communication, Scottish Trauma Audit Group), it is apparent that aortic injury is seen relatively infrequently by Accident and Emergency staff. The low rate of hospital presentation of aortic injury, together with acknowledged difficulties in diagnosis, underlines the importance of paying particular attention to the mechanism of injury and of adopting a high index of suspicion if significant forces are involved.

There is currently much debate as to which investigations are most appropriate (CT scan, transoesophageal echocardiography or arch aortogram) [31-39]. Similarly, there is also debate regarding treatment, with the traditional view that all patients should undergo immediate surgical repair being challenged. Some authorities advocate repair "semi-electively" after the institution of medical therapy (vasodilators, β -blockers and careful control of intravenous fluids), whilst others claim that patients with certain injuries and high risk groups, such as the elderly, may be treated with conservative therapy continued indefinitely [40-43]. Despite this controversy, there is general agreement that the diagnosis and extent of aortic injury should be established as quickly as possible, so that the preferred treatment can be instituted. It is therefore crucial that the definitive investigations are performed and evaluated rapidly and accurately. Patients will be best served if an established policy for urgent investigation is in place for all those with suspected aortic injury.

Despite the fact that aortic injuries present relatively infrequently to hospital, this study demonstrates that they are implicated in a significant number of deaths from trauma. The vast majority of these deaths occur at the scene of accidents. The greatest potential for reducing the number of deaths from thoracic aortic injury therefo-

re lies with accident prevention measures. Such measures are of two basic types. Those in the first type aim to reduce the number of accidents occurring. Examples include alterations in road layout and speed restrictions. The other type of measures are those which aim to minimise the injuries sustained in those accidents which do occur. Further research is required in order to establish the potential benefits of alterations in vehicle design (such as airbags in cars, position and design of seats in aircraft).

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Quantifying injury and predicting outcome after trauma

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Abstract

The Abbreviated Injury Scale (AIS), Injury Severity Scale and TRISS methodology comprise a mathematically sound system for the analysis of injuries and injured patients. This system is of value for research and audit and has potential applications in forensic medicine, such as its use as a tool to assist the classification and analysis of injuries sustained by those injured in mass disasters. © 1998 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Injury severity score; Trauma score; Probability of survival

1. Aim

This article reviews both the Abbreviated Injury Scale (AIS) scoring system together with its derived Injury Severity Score (ISS) and the associated TRISS methodology which allows probabilities of survival to be generated. The possible ways in which Injury Severity Scoring and TRISS methodology may be applied to clinical and forensic medical practice are explored.

2. Introduction

The Abbreviated Injury Scale (AIS) scoring system and its derived ISS for

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quantifying anatomical injury are now well established and have been used for many years to assist study of the epidemiology and management of trauma [1]. The AIS was initially developed in an attempt to assist research into and investigation of injuries sustained in road traffic accidents [2]. The basis of the AIS is to allocate specific codes to specific injuries and also a score comprising an integer between 1 and 6 (see Table 1).

The AIS which was first published in 1971 was devised by a collaborative team comprising members from the American Association for Automotive Medicine, the Society of Automotive Engineers and the American Medical Association [2]. Since the first edition, the AIS has been revised and updated on several occasions, in order to broaden its applicability to include other forms of trauma, including penetrating injury, electrical injury, hypothermia, burns and smoke inhalation [3,4]. Additionally, the latest (1990) revision of AIS incorporates some changes in an attempt to more accurately code and score the injuries sustained by young children, as compared to adults [4].

For the multiply injured patient, analysis and coding of each injury inevitably generates a large number of individual injury scores. Soon after the first publication of the AIS, it was recognised that in order to obtain a score which would accurately reflect the severity of all injuries, simply taking the highest or Maximum AIS was insufficient [5]. Instead, in 1974 Baker developed the concept of a whole body score or Injury Severity Score (ISS), derived from the three highest individual AIS scores in different body regions (see below) [5]. The ISS is now the accepted standard for trauma scoring,

Table 1
AIS coding of rib cage injuries, demonstrating the need for detailed and accurate data

Injury description	AIS code	AIS score
Ribcage injury-NFS	450299.1	1
Rib cage contusion	450202.1	1
Rib fracture-NFS	450210.1	1
1 rib fracture	450212.1	1
1 rib fracture with haemo-/pneumothorax	450214.3	3
2–3 rib fractures at any location, or multiple fractures of a single rib, with stable chest or NFS	450220.2	2
2–3 rib fractures with haemo-/pneumothorax	450222.3	3
>3 rib fractures on 1 side and ≤ 3 on the other, with a stable chest or NFS	450230.3	3
>3 rib fractures on 1 side and ≤ 3 on the other, with haemo-/pneumothorax	450232.4	4
>3 ribs on both sides, with stable chest or NFS	450240.4	4
>3 rib fractures on both sides with haemo-/pneumothorax	450242.5	5
Open/displaced/comminuted fracture of ≥ 1 rib	450250.3	3
Open/displaced/comminuted fracture of ≥ 1 rib with haemo-/pneumothorax	450252.4	4
Flail chest without lung contusion	450262.3	3
Flail chest with lung contusion	450264.4	4
Flail chest (unstable chest wall) bilaterally	450266.5	5
Flail chest in a patient aged <15 years old	450268.5	5

NFS = not further specified. This code and associated score is allocated when details of an injury are vague or incomplete. In this situation, the score attributed to an injury may be a considerable under-estimate (see text).]

and is used in research and in both regional and national review of trauma care all over the world [1,6–11].

In order to compare patients' hospital presentation with their outcome (measured in terms of survival or death), a method named the TRISS method was developed, using the AIS as its basis [12,13]. By using data from thousands of injured patients, TRISS methodology enables predicted probabilities of survival to be calculated and allows the identification of unexpected deaths and unexpected survivors (as described below), thus facilitating evaluation of trauma care [12–22].

3. The abbreviated injury scale

The AIS code book (1990 revision) contains detailed descriptions of more than 2000 injuries. Each injury has been allocated a unique seven digit code number. The last digit of each code follows a decimal point and consists of an integer between 1 and 6. This last digit is the AIS score given to that injury. The AIS attributes a score between 1 and 6 to each individual injury, as follows:

AIS 1	=	minor injury
AIS 2	=	moderate injury
AIS 3	=	serious injury
AIS 4	=	severe injury
AIS 5	=	critical injury
AIS 6	=	fatal injury

In order to correctly code (and thus score) an injury, it is first necessary to ensure that the data sources (comprising clinical case notes and/or autopsy reports) record injuries accurately and in detail. Insufficient details may lead to the severity of an injury being significantly under-estimated and inadvertently under-scored. For example, if it is recorded that a patient simply has rib fractures, this scores 2, whereas if the exact number and location are recorded, this may score much higher (see Table 1). This is particularly important with certain specific injuries, such as those involving the spinal cord.

4. Injury severity score

The ISS is designed to reflect whole body injury. It was developed from a mathematical analysis of thousands of injured patients [5]. To calculate the ISS from an array of AIS scores for a patient, the three highest AIS scores in different body regions are squared then added together. ISS considers the body to comprise six regions as follows:

Table 2
Example of a multiply injured patient

Injury description	AIS score	Body region
Closed linear undisplaced temporal skull fracture	2	Head/neck
Bilateral pulmonary contusions	4	Chest
Major aortic arch rupture at its root	5	Chest
Minor (superficial) mesenteric contusion	2	Abdomen
Massive splenic rupture with hilar disruption	5	Abdomen
Multiple widespread superficial abrasions	1	External

1. Head/neck
2. Face
3. Chest
4. Abdominal or pelvic contents
5. Extremities or pelvic girdle
6. External (skin)

Possible ISS scores range from 1 to 75. The highest score of 75 may be achieved by a patient having a critical injury of AIS score of five in three different body regions (in this case, $ISS=5^2+5^2+5^2=75$). In addition, any patient with an AIS score of six (considered unsurvivable) is automatically given an ISS of 75. An example of calculating the ISS is shown below:

$$ISS = (5)^2 + (5)^2 + (2)^2 = 54$$

In the example shown, the three injuries contributing to the ISS are the aortic injury, the splenic injury and the skull fracture (see Table 2). The other injuries make no contribution. The ISS system is therefore open to criticism on the grounds that it fails to take account of all the injuries (e.g. any second or subsequent (lesser) injury within the same body region). In practice, however, the system works well and demonstrates good correlation with outcome in terms of survival or death. Studies have shown that patients who reach hospital alive with ISS scores of greater than 15 have a risk of death of more than 10% [16,19]. The accepted definition of major trauma, both in clinical practice and in research is therefore an ISS of greater than 15.

Although ISS correlates well with mortality, it is important to realise that it is a non-linear scoring system and also that some scores (eg. 7, 15, 67) are impossible to attain. Thus, when analysing cohorts of patients, it is more statistically correct to use a median value than a mean.

5. Predicting probability of survival (P_s)

The ISS has been validated as a good measure of anatomical injury, in terms of actual damage and physical disruption to body tissues [5,23]. However, in order to most effectively evaluate the likely effect of a set of injuries on a particular patient, in terms

of whether he or she is likely to survive having reached hospital, two other important factors need to be taken into account. These factors are the patient's age and physiological derangement (as defined below) on arrival at hospital, irrespective of any prehospital intervention. Combining the ISS with age and physiological derangement by a method known as TRISS methodology allows a probability of survival for any patient to be calculated [12,13].

TRISS methodology is mathematically rather complex and therefore usually remains within the domain of statisticians. Physiological derangement is measured by the Revised Trauma Score (RTS). The RTS is derived and adapted from the Trauma Score, and has been validated for use in TRISS methodology [13,24]. The RTS is based upon three physiological variables at hospital presentation: the respiratory rate, the systolic blood pressure and the Glasgow Coma Scale. Coded values are attributed to each of these variables, to which a weighting factor is applied prior to the scores being added to yield the RTS (see Table 3). The weighting factors applied to each of the three physiological variables in the RTS reflect their relative importance in predicting outcome after trauma. The weighting factors were mathematically derived using regression analysis of data from more than 28 000 patients [24].

Once a patient's RTS has been calculated, his or her probability of survival can be calculated using the equation:

$$\text{Probability of survival } (P_s) = \frac{1}{(1 + e^{-b})}$$

Table 3
The revised trauma score (RTS)

Physiological variable	Coded value	Multiplying (weighting) factor	Score
Glasgow coma scale			
13-15	4		
9-12	3		
6-8	2		
4-5	1		
3	0	0.9368	x
Systolic blood pressure (mmHg)			
>89	4		
76-89	3		
50-75	2		
1-49	1		
0	0	0.7326	y
Respiratory rate (breaths per minute)			
10-29	4		
>29	3		
6-9	2		
1-5	1		
0	0	0.2908	z
Revised Trauma Score = x + y + z			

where e is the natural logarithm and $b = b_0 + b_1(\text{RTS}) + b_2(\text{ISS}) + b_3(A)$.

The value A is a weighting factor to allow for the age of the patient. b_0, b_1, b_2, b_3 are weighted coefficients which differ according to whether the patient has sustained blunt or penetrating trauma. The coefficients are derived from Walker-Duncan regression analysis of data from tens of thousands of trauma patients – these coefficients vary according to which population the patient is being compared to [16,19]. Thus, for example, a patient with a certain ISS, RTS and age would be predicted to have a different probability of survival according to whether he or she was being treated in the US or the UK, since the levels of trauma care differs between the two countries [16,19].

5.1. Example calculation of probability of survival (P_s)

Suppose the patient with an ISS of 54 in the example given above was a 26-year-old female pedestrian knocked down by a bus and that when she presented to hospital she had a Glasgow Coma Scale of 14/15, a systolic blood pressure of 136 mmHg and a respiratory rate of 30 breaths per minute. Her RTS is thus 7.55, allowing her probability of survival to be calculated using the following UK coefficients:

$$b_0 = 0.945$$

$$b_1 = 0.642$$

$$b_2 = -0.122$$

$$b_3 = -1.866$$

$$A = 0$$

$$\text{Thus, } b = 0.945 + (0.642 \times 7.55) + (-0.122 \times 54) + (-1.866 \times 0) - 0.7959$$

$$P_s = \frac{1}{(1 + e^{0.7959})} = 0.31$$

In other words, it would be predicted that this woman would have a $0.31 \times 100\%$ ($=31\%$) chance of surviving this injury in the UK. Patients who survive with a $P_s < 0.5$ are regarded as unexpected survivors and those who die with a $P_s > 0.5$ as unexpected deaths. It must be emphasised that the term unexpected death does not necessarily equate with mis-treatment/medical negligence. The probability of survival can, however, act as a useful guide as to the overall severity of a particular patient's injuries.

6. Comparing cohorts of patients

By means of further complicated mathematics, a comparison of the actual outcome with predicted outcome for a large number of patients treated within a certain hospital allows a conclusion to be reached as to whether the overall treatment provided for

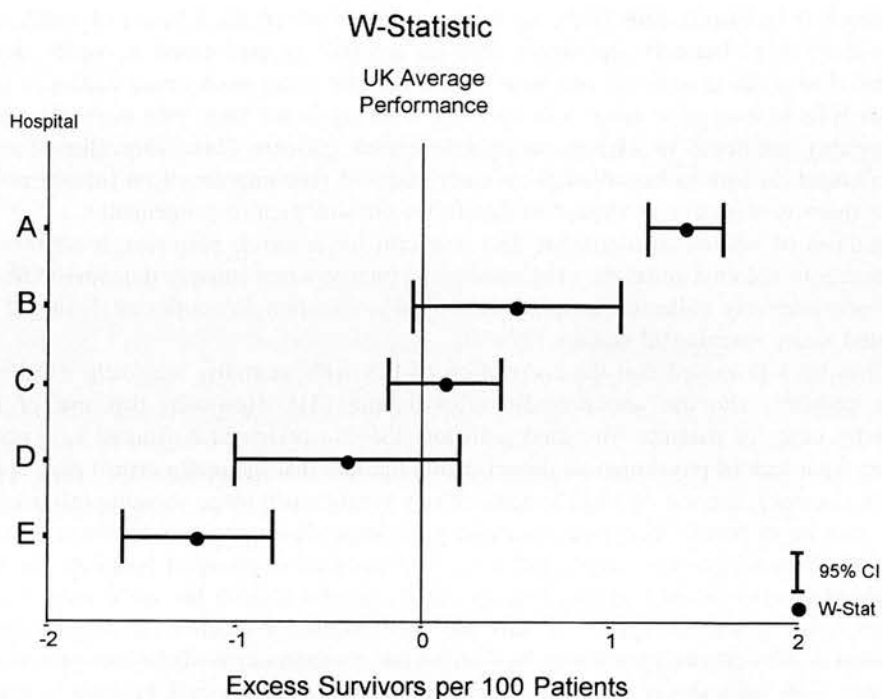


Fig. 1. *W* statistics and confidence intervals for five hospitals.

trauma patients by that hospital is statistically better, worse or no different from the national average (obtained from the national database comprising thousands of patients). This conclusion is presented in what is known as a *W* statistic [19,20]. The *W* statistic is expressed as the number of excess survivors per 100 patients with major trauma, compared with what would be expected from the national database. Depending on the size of the database of the hospital being studied, the difference between the *W* statistic and what would be expected may be statistically significant. This is most easily portrayed in graphical form where confidence intervals can be added to each hospital's *W* statistic. An example is shown in Fig. 1. In Fig. 1, it can be seen that hospital A is performing statistically significantly better than expected and that hospital E is performing significantly worse. Hospitals B, C and D are not significantly different from that predicted.

7. Applications in medical and forensic practice

The AIS scoring system may usefully assist clinicians and pathologists to document injuries in a standardised way and help to cultivate a discipline of accurately describing and recording wounds. It may be applied both to patients who survive and to those who die following injury. For it to be useful, both the clinical and pathological information

on which it is based needs to be detailed and accurate. In the context of death after trauma, it is particularly important that an autopsy is performed in order not to underestimate the severity of the injuries and thereby under-score them [25].

The RTS is used as a triage tool by those working in the front line in Accident and Emergency medicine to identify critically injured patients [26]. This allows senior experienced doctors to be called at an early stage of resuscitation of an injured person when there is objective evidence of significant physiological derangement.

Analysis of injuries according to ISS is useful for research purposes. It enables the researcher to obtain a complete epidemiological picture when autopsy data are combined with prospectively collected hospital data — this situation in south-east Scotland has enabled many meaningful studies [27–30].

It has been proposed that the correlation of ISS with mortality may help to identify those patients who die unexpectedly after trauma [31]. However, this use of ISS, whereby cases of patients who died with low ISS are reviewed is limited to a certain extent, by a lack of physiological data. Despite the fact that the mathematics may appear a little daunting, the use of TRISS methodology yields much more valuable information. This may be of benefit in comparing different systems of trauma care between different hospitals. When a problem with a particular unit, hospital or group of hospitals has been identified, it may be investigated and remedied, thereby closing the audit loop. TRISS methodology may be used to yield individual probabilities of survival for patients treated in hospital. This allows attention to be focused on an examination of the care provided to patients with unexpected deaths. A review process of unexpected hospital deaths is critical to the improvement of hospital care. To be effective, peer review of these cases needs to involve clinicians from a variety of disciplines.

Medical practitioners are often asked (by the police, relatives, the media and most importantly, legal authorities and agents) to classify the severity of a particular injury or set of injuries. Often, the answer provided is rather subjective however, the AIS provides an excellent objective way of classifying any individual injury as being minor, moderate, serious, severe, critical or fatal. This may assist in an explanation of the seriousness of a certain injury, particularly in relation to cases of assault. The medical expert witness may use the AIS, ISS and TRISS methodology as an aid when providing opinions on the severity and survivability of injuries sustained by particular individuals. This information is available from many hospitals in the UK, US, Canada and numerous other countries which prospectively collect relevant data [14,16,18–20].

The AIS and its derived ISS have further potential uses in forensic practice. In particular, they may be useful in the aftermath of mass disasters, as a means of classifying the injuries sustained. This would facilitate subsequent analysis of injury patterns.

8. Abbreviations

AIS	=	Abbreviated Injury Scale
ISS	=	Injury Severity Score
RTS	=	Revised Trauma Score

P_s = Probability of survival (as calculated using TRISS methodology)

TRISS is an acronym from **TR**auma score and **I**njury **S**everity **S**core.

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Hanging Deaths in Children

Jonathan P. Wyatt, Polly W. Wyatt, Tim J. Squires, and Anthony Busuttill

Relatively little is known about death in children following hanging. This 12-year retrospective study in south-east Scotland revealed 12 such deaths among children <15 years of age, involving 10 boys and 2 girls. The rate of hanging deaths was 0.7 deaths/100,000 children/year and was equal to that from falls in children during this time period. The children who died following hanging were aged between 4 and 14 years. All 12 children were in cardiac arrest when found, and 11 were declared dead at the scene, demonstrating the limited potential to reduce the death rate through improved treatment. Scrutiny of the circumstances surrounding each death suggested that 6 of the deaths were accidents and 6 were suicides. There appears to be some, albeit limited, potential to prevent some hanging deaths in children through increased parental supervision, education, and restriction of access to ligatures.

Key Words: Hanging—Pediatric death—Accident prevention—Suicide.

Death from hanging among adults is recognized to be a common occurrence in many parts of the world (1-3). In contrast, hanging deaths in children appear to be uncommon, although the exact epidemiology of this occurrence is relatively unknown. This is reflected in the literature: much of the published work has taken the form of one or two case reports rather than large series of cases (4-10). Examination of the cases of a complete series of children who died following hanging is necessary to allow an insight into how these deaths might be prevented.

SUBJECTS AND METHODS

Deaths due to hanging in children <15 years of age in the Lothian and Borders regions of southeast Scotland during the period from 1985-1996 were identified from records in the Forensic Medicine Unit (FMU) and the records of the procurators fiscal, the legal officials with the common law jurisdiction for the investigation of sudden or violent deaths. The dataset was confirmed to be complete by checking the records of all children who died following trauma during these 12 years and by checking against data held by the Registrar General for Scotland.

The deaths of all children who die following injury in south-east Scotland are investigated by the police and postmortem examination is performed under the instructions of the procurator fiscal. The circumstances surrounding the deaths, the treatment provided, and the findings at autopsy and after toxicologic analysis were obtained from a variety of sources, including the records of the FMU, procurators fiscal, police, ambulance, and hospital.

RESULTS

Rate of Pediatric Hanging Deaths

One hundred and forty-three children died after trauma in the 12-year period under review: 8 deaths

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icides, 5 as equivocal or possible suicides (17%), as homicides (7%), and 20 as accidents (67%) (20,21). The 6 suicides in the children in this series (aged between 11 and 14 years) are of considerable concern. This concern mirrors that regarding the recent rise in the suicide rate among children 15 years of age in the United States (26). However, equivalent figures for England and Wales do not show any similar recent increase (27).

The first obvious step in attempting to prevent suicide in children is to identify those children at risk (28). Of the 6 suicides in this study, only 1 child had voiced previous suicidal ideation: this child appeared to have unaddressed psychological problems. The remaining 5 children appeared to have committed suicide impulsively during what responsible adults might consider relatively minor stressors; the extent to which these children were experiencing other non-disclosed difficulties (e.g., bullying at school) is unknown.

CONCLUSIONS

Hanging is responsible for a small but significant number of deaths among children. Combining this series with previous reports allows a broad classification of pediatric hanging deaths according to age and circumstances (Table 3). Although the way forward in terms of preventing all of these deaths is not clear, there appears to be potential to prevent some pediatric hanging deaths through a combination of manufacturing legislation, increased parental supervision, education, and restricting young children's access to ligatures.

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A comparison of fatal with non-fatal knife injuries in Edinburgh

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Abstract

Assault using a knife is a common problem in the United Kingdom. Between February 1992 and December 1996, 120 individuals died or received hospital treatment in Edinburgh after being assaulted with a knife. Twenty individuals (17%) died as a result of their injuries. Comparison of the survivors with non-survivors revealed both groups to have similar age and sex distributions, but those who died had significantly more severe injuries when scored according to the Abbreviated Injury Scale. Eight individuals died of unsurvivable chest injuries at the scene of the attack and of the remainder, only five reached hospital with signs of life. Analysis of hospital treatment using TRISS methodology revealed there to be two unexpected survivors and no unexpected deaths. The risk of death appears to depend mostly upon injuries sustained and also to a lesser extent upon other factors such as alcohol consumption and the presence of a bystander capable and willing to request emergency medical assistance. There does not appear to be much potential to save lives by improving hospital treatment for those assaulted with a knife in Edinburgh. Instead, greater focus needs to be placed upon rapid transfer to hospital and upon restricting the possession and use of knives. © 1999 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Assault; Knife; Risk of death; United Kingdom

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1. Introduction

The rate of homicide in Scotland (and the rest of the UK) remains relatively low when compared with the US [1–5]. In the US, the use of guns accounts for most homicides [4–7]. In contrast, in Scotland, the use of guns is responsible for only a small proportion of homicides (nine out of 111 (8%) in 1994), whereas the use of knives and other sharp instruments account for a large proportion (58 out of 111 (52%) in 1994) [1]. Indeed, the use of knives in assaults in Scotland in recent years has aroused understandable concern [8].

In order to examine the relative risks of death after assault with a knife and to investigate why some patients die whilst others survive, it is necessary to study a complete population (including both deaths and survivors). Sharp force injuries may be classified by those trained in forensic medicine according to the relative length of the wound compared with its depth ('stab' wounds, 'slash' wounds). However, in this study, many of the wounds were assessed by hospital doctors without special forensic expertise, hence all wounds are simply referred to as 'stab' wounds.

2. Methodology

All individuals who were admitted to hospital or who died before reaching hospital having been assaulted with a sharp implement within the city of Edinburgh and its associated suburbs (approximate population 0.5 million people) during the period February 1992–December 1996 were identified and studied using Forensic Medicine and Scottish Trauma Audit Group records. Only those injuries which appeared to have resulted from assaults were studied: self-inflicted trauma was not included in the analysis. All those patients who presented to hospital following a knife injury were admitted for treatment (and included in this study) where there was any possibility of significant injury to an underlying structure or organ. Patients who presented with minor, superficial skin wounds which did not require hospital admission were not included in the study. It is possible that some individuals may have survived after sustaining deep penetrating injuries and choosing not to seek medical attention — such individuals, if any, would not have been included in this study.

2.1. *Deaths following stabbing*

The deaths of all those individuals who die following injury in Edinburgh are investigated by the Procurator Fiscal in several ways. Firstly, police officers make enquiries as to how, why, where and when the incident occurred. Secondly, forensic pathologists within the Forensic Medicine Unit of the University of Edinburgh perform autopsies in all cases of death following assault: these autopsies include the taking of relevant toxicological samples.

Data were collected for those individuals who died following stabbing from a variety of sources, including ambulance and hospital records, police and Procurator Fiscal reports, autopsy and toxicological records. Details of the injuries sustained as a result of

the stabbing incident were obtained from autopsy examination. This enabled all injuries to be scored according to the Abbreviated Injury Scale (1990 revision) [9], allowing Injury Severity Scores to be calculated for each patient [10]. The Abbreviated Injury Scale and its derived Injury Severity Score (ISS) have become accepted international tools used in the study of various types of trauma [10]. The system scores each injury from 1 (minor) to 6 (unsurvivable). The three highest scores in different body regions for each patient are then individually squared and added together to produce an Injury Severity Score [10]. The range of possible ISS values is 1–75 (patients with an unsurvivable injury are automatically given a score of 75).

2.2. Survivors and hospital deaths after stabbing

Data were collected prospectively by the Scottish Trauma Audit Group on all patients who were brought to hospital in Edinburgh after being stabbed [11]. Every patient who was stabbed was followed up until hospital discharge or death. Data collected included: the time of stabbing and time of hospital presentation, the physiological state of the patient at hospital presentation and details of the injuries sustained: these were obtained from clinical examination, X-rays, CT scans, operative findings and/or autopsy examination. This information enabled all injuries to be scored according to the Abbreviated Injury Scale (1990 revision) [9]. This yielded Injury Severity Scores and Revised Trauma Scores for all patients. The Revised Trauma Score is calculated from the Glasgow Coma Scale, respiratory rate and systolic blood pressure and is a reflection of a patient's physiological derangement on hospital presentation [12]. By means of comparison with the national trauma database, using relatively complex mathematics, combining anatomical injuries (as measured by the ISS) with physiological derangement (Revised Trauma Score) and the age of the patient, allows the expected probability of survival for each patient to be calculated [12,13].

Data were also obtained from records of the hospital-based flying squad ambulance ('Medic One') in Edinburgh. This flying squad team comprises two doctors, a nurse and two paramedics. The team leader is always an Accident and Emergency doctor trained in Advanced Life Support techniques, including anaesthesia and emergency thoracotomy.

3. Results

During the study period there were 20 deaths (17 males, three females) following assault by stabbing. A further 100 individuals (96 males, four females) survived stabbings, following admission to hospital. In most cases, although the weapons were described by those injured as being knives, these weapons were never recovered and compared with the wounds. Additionally, in some cases, the victim did not see the weapon. It is therefore possible that a proportion of the injuries attributed to knives were actually caused by other sharp implements.

The age profile of survivors compared with non-survivors is demonstrated in Fig. 1. The age range found in both categories was similar: survivors 15–62 years, non-

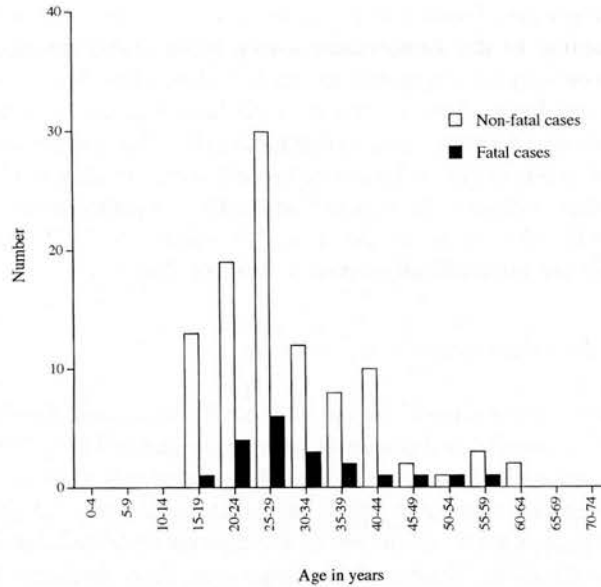


Fig. 1. Age distribution of non-fatal and fatal stabbing victims.

survivors 19–58 years. The peak in frequency of non-fatal stabbings in the 25–29 year category is mirrored by the deaths.

The Injury Severity Scores of all those stabbed is shown in Fig. 2. The majority (83%) of survivors sustained injuries with an ISS of less than 15 (an ISS of more than 15 is an accepted definition of major trauma [11]). In contrast, 95% of the fatal cases scored an ISS greater than 15. Comparing the groups using a chi-square test revealed that significantly more non-survivors had sustained 'major trauma' ($\chi^2=273.3$ and $P<0.0001$).

Twelve of the 20 individuals who died after being stabbed showed no signs of life when found, three died at the scene or in transit to hospital (within the physician-led hospital based flying squad, 'Medic One') having been found alive and only five patients reached hospital alive, but died later. Calculation using TRISS methodology according to age, physiological indices and anatomical injuries revealed all five individuals to have probabilities of survival (Ps) of less than 50% — all were therefore classed as 'expected' deaths, rather than 'unexpected deaths' (Table 1) [12–14]. By contrast, the 100 survivors of stabbing assaults had probabilities of survival ranging from 4.0% to 99.9% and included two 'unexpected survivors' (defined as survival with probability of survival of less than 50%).

Details of those who died, together with their most severe injuries, are shown in Table 1. Eight individuals had cardiac injuries acknowledged to be unsurvivable (Abbreviated Injury Scale=6, Injury Severity Score=75). Apart from the obligatory presence of an 'attacker', half of the 12 'potentially survivable' assaults occurred when the victim was otherwise alone and unable to summon immediate help. This may have severely compromised their chances of survival.

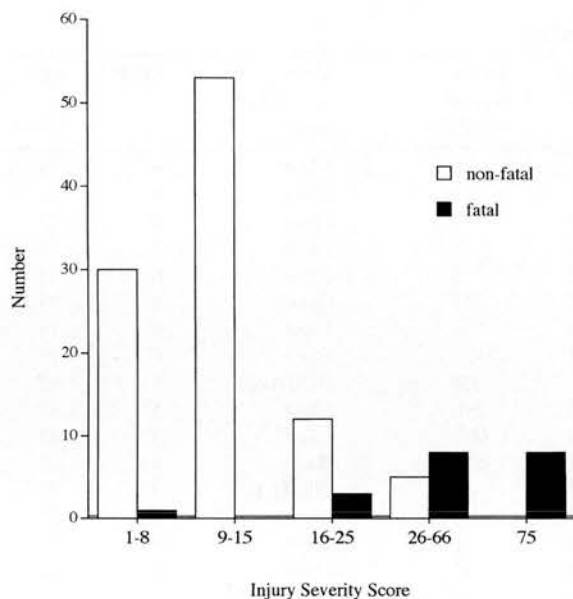


Fig. 2. Outcome according to ISS.

The maximum Abbreviated Injury Scale scores (MAIS) were recorded for all 120 cases, according to which of the six standard anatomical regions within which they fell. These data are displayed graphically in Fig. 3. The seventh category of 'combined' represents cases where more than one body region scored the same MAIS. There were significantly more chest injuries responsible for the MAIS score in the fatal group, than the non-fatal ($\chi^2=39.1$ and $P<0.0001$). The anatomical component 'head and neck' was also over-represented in the fatal category when compared to the non-fatal one ($\chi^2=102.6$ and $P<0.0001$). No fatalities resulted from injuries where the MAIS score occurred in the anatomical regions of the face, extremities or external.

4. Discussion

Many more males were stabbed than females during the study period. In keeping with this male predominance, the vast majority of those who died were male. Similarly, the majority of victims of stabbings were aged between 15 and 34 years. These findings are consistent with data from elsewhere [15–17].

Many of those who died after being stabbed had alcohol present in their bloodstream, urine or vitreous fluid at the time of death. The corresponding data for those who inflicted the fatal stabbings or those who survived being stabbed is not complete, since blood alcohol levels are not routinely collected on patients presenting alive to Accident and Emergency. However, it is recognised from previous studies that alcohol plays a role in a significant proportion of violent crimes [18–20]. In addition to its potential role

Table 1
Details of the fatal stabbings

No.	Age	Sex	Blood alcohol (mg/dl)	Most severely injured body region	MAIS	ISS	Ps (%)	Place of death
1	22	F	0	Chest	6	75	–	Scene
2	25	F	0	Chest	6	75	–	Scene
3	25	M	?	Chest	6	75	–	Scene
4	25	M	235	Chest	6	75	–	Scene
5	31	M	66	Chest	6	75	–	Scene
6	33	M	355	Chest	6	75	–	Scene
7	36	M	0	Chest	6	75	–	Scene
8	48	M	(232 ^a)	Chest	6	75	–	Scene
9	34	F	354	Head/neck	5	45	–	Scene
10	50	M	360	Chest	5	42	–	Scene
11	21	M	(166 ^b)	Chest	5	42	0.4	Hospital
12	57	M	(357 ^a)	Chest	5	38	–	Scene
13	41	M	0	Chest	5	35	–	Scene
14	19	M	38	Chest	5	27	–	Medic 1
15	22	M	0	Chest	5	26	1	Hospital
16	29	M	145	Chest	5	26	1	Hospital
17	29	M	171	Head/neck	4	21	–	Medic 1
18	22	M	216	Abdomen	4	17	4	Hospital
19	39	M	145	Chest	4	17	4	Hospital
20	27	M	?	Head/neck	2	5	–	Scene

^aVitreous sample.

^bUrine sample.

Ps, probability of survival; MAIS, maximum AIS score; ?, toxicology result not available.

in causing someone to be stabbed, alcohol may also play a part in determining both the injuries received and whether those injuries resulted in survival or death. Firstly, alcohol may render a person less capable of defending himself or escaping quickly from a potentially violent situation. Secondly, having been stabbed, alcohol may blur an individual's perception of the severity of their injuries and adversely affect their initial response in terms of seeking urgent medical attention. Thirdly, the influence of alcohol may reduce a stabbed person's ability to apply pressure and limit bleeding from an external wound. Fourthly, the presence of alcohol may limit the ability of someone to call for emergency medical help — this is particularly pertinent in those cases where there were no witnesses to the stabbing incident.

Fig. 2 demonstrates that the outcome after a stabbing injury (in terms of survival or death) can be explained to a large extent by the severity of the injuries sustained. All except one of those who died had injuries consistent with major trauma (Injury Severity Score of greater than 15). Most of the fatal injuries involved stabbings to the chest or neck — these body regions being implicated significantly more frequently in causing the MAIS than other body regions. These results confirm those of previous studies which emphasise the role of injury to the heart and major vessels in causing death after stabbing [16,21].

Use of the Abbreviated Injury Scale and the associated TRISS methodology enables a

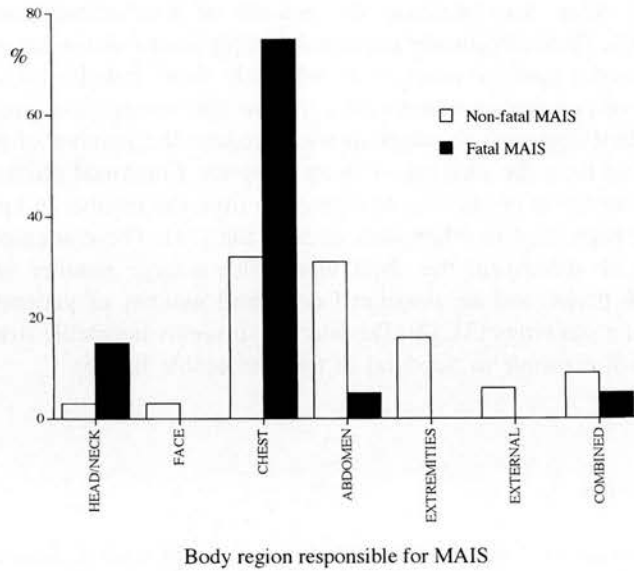


Fig. 3. Body regions responsible for MAIS in fatal and non-fatal stabbings.

critical analysis of the hospital treatment of injured patients [11–14,22–24]. All five patients who died having reached hospital with signs of life had very low predicted probabilities of survival, indicating that medical intervention had little chance of saving their lives. Indeed, the fact that there were two unexpected survivors, but no unexpected deaths, amongst those stabbed is an indication that the hospital system for treating such patients is working efficiently. As a result, there is little evidence for any potential to 'save lives' through improved hospital treatment. This is in contrast to previous studies which have identified deficiencies in trauma management in many UK hospitals [22,25]. Table 1 does demonstrate that 12 of the 20 individuals who died had potentially survivable injuries, but most failed to reach hospital alive. For example, the one patient who died with an ISS of less than 15 sustained a neck injury which resulted in pre-hospital exsanguination. Unfortunately, if a stabbed person is unable to immediately summon help, either because of the severity of the injuries or because of the effects of alcohol or drugs, he/she may not receive prompt medical attention. This may result in death from injuries which were potentially survivable.

The need for rapid transfer to hospital after serious penetrating injury to allow definitive surgical intervention is becoming increasingly recognised and is beginning to influence pre-hospital and hospital care [26–28]. The application of pressure and bandages in the pre-hospital setting to stop haemorrhage from briskly bleeding skin wounds is of obvious benefit. Whilst such simple measures may be performed rapidly, other interventions, particularly the insertion of intravenous cannulae and administration of intravenous fluids are time-consuming [29]. These pre-hospital interventions may be counter-productive in two respects. Firstly, increasing the blood pressure by giving intravenous fluids may result in an increased rate of haemorrhage and secondly, the

additional time delay may increase the amount of haemorrhage before definitive treatment [29,30]. These arguments particularly apply in the urban environment of this study, where transfer times to hospital are relatively short. Policies for the pre-hospital care of victims of penetrating trauma need to take this information into account.

Perhaps the best approach to adopt to try to reduce the number of stabbing deaths would be to try to limit the carrying of sharp weapons. Combined efforts by the media, and emergency medicine physicians, to attempt to limit the number of knives carried on the streets have been tried in other parts of Scotland [31]. These attempts resulted in a certain amount of success in the short term, with a large number of knives being collected by the police and an associated decreased number of patients presenting to hospital following stabbings [31,32]. Despite this, it seems inevitable that some assaults by 'stabbing' will continue in Scotland in the foreseeable future.

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Fatal falls down stairs

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Abstract

Fatal falls down stairs in south-east Scotland were studied using prospectively collected data between 1992 and 1997. 51 individuals, comprising 27 men and 24 women with mean age 68.9 years, died following falls down stairs, 30 (59%) of which were unwitnessed. 43 (84%) individuals died following falls within their own homes. Overall, 27 (53%) fatal falls resulted in death at the scene of the accident. Analysis of injuries according to the Abbreviated Injury Scale yielded injury severity scores (ISS) of between 5 and 75, but only four individuals had injuries recognised to be unsurvivable (ISS = 75). Injury to the brain and/or spinal cord was responsible for the vast majority of most severe injuries. The results demonstrate that stairs represent a significant hazard for the elderly. Most of the deaths in the pre-hospital setting appeared to be more the result of the fact that the victim was alone and unable to summon assistance, rather than as a result of unsurvivable injuries. Consideration needs to be given to both how the safety of stairs can be improved and whether a particular elderly person can safely cope with stairs.

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1. Introduction

Falls are a relatively common cause of death following trauma in Scotland in all age groups [1]. The epidemiology and pattern of injuries in high (free) falls has been well documented, but in contrast, relatively little has been written about falls down stairs [2–8]. It has been demonstrated that, as might be predicted, the severity of the injuries sustained in a high fall is related closely to the height of that fall [9, 10]. Similarly, the risk of death increases with increasing height of fall, although other factors (such as the surface landed upon and impact position of the body) are important [3, 7, 11]. Very high falls (of more than 30 m) are almost always fatal, although there have been remarkable exceptions [3, 12, 13].

Unlike free falls, which can be categorised according to the length of fall, falls down stairs cannot be easily classified, although there appears to be some potential

for computer simulation to be of some assistance in this respect [14]. The way that a body falls, slides or tumbles down stairs may depend upon the underlying cause of the fall. Whether the fall was caused by a stumble, a push, collapse following a medical condition or the influence of drugs or alcohol, may also have an effect upon the ability of an individual to protect himself/herself during the fall. This, in turn, may influence the nature and pattern of the injuries sustained.

In those falls which are unwitnessed, the actual length of the fall may be unclear. In addition, rather than depending solely upon the length of the fall, the nature and pattern of injuries sustained may depend also upon a variety of other factors, such as the steepness of the stairs and the surface landed upon (e.g. carpet, wood or stone). Injuries may also result during falls by impact against walls, bannisters, other obstacles or ornaments on the stairs. This study was undertaken in order to examine the epidemiological and pathological findings in fatal falls down stairs, with particular reference to how deaths might be prevented.

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2. Methods

All fatalities following trauma in Lothian and Borders are investigated by the police on the instructions of the Procurator Fiscal. Police officers prepare a detailed report of the circumstances surrounding each accident, thus providing an insight into how each accident occurred. Similarly, detailed autopsies are performed by the Forensic Medicine Unit of the University of Edinburgh on all traumatic deaths in Lothian and Borders regions.

Deaths following falls down stairs between 1992 and 1997 in Lothian and Borders regions of south-east Scotland were studied. Data sources for the information analysed included: police reports on these deaths, autopsy findings, post-mortem toxicology results, ambulance records, hospital case notes and the database of the Scottish Trauma Audit Group. The Scottish Trauma Audit Group is an organisation funded by the Scottish Office which prospectively collects data on injured patients in Scotland [15]. Deaths following falls which were not strictly down stairs, but which were free falls over bannisters and down stairwells, were excluded from the analysis. The injuries sustained by all those who died after falls down stairs were scored according to the Abbreviated Injury Scale (1990 revision), allowing injury severity scores to be generated [16, 17].

3. Results

During the six years 1992-1997, there were 51 deaths (27 men, 24 women) following falls down stairs in south-east Scotland. The mean age of those who died was 68.9 years, with a range of 19-95 years (Fig. 1). 43 fatal falls (84%) occurred within the victim's own home. The majority (27/43) of those who

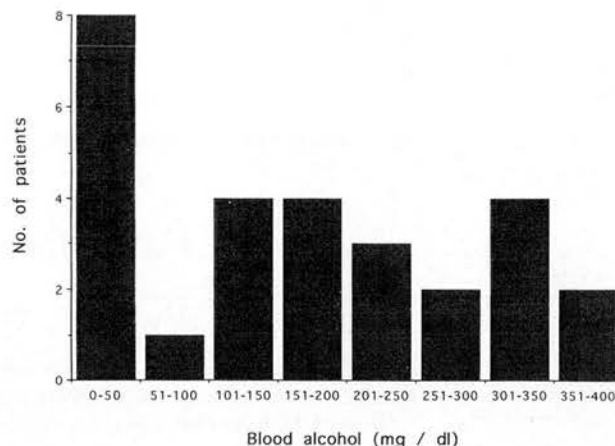


Fig. 2. Blood alcohol levels of 28 patients.

fell down stairs in their own homes lived alone, with 17 of these being aged more than 65 years.

30 (59%) of the falls were unwitnessed, the remaining 20 were witnessed or the noise of the fall was heard and responded to. 27 individuals (53%) died at the scene (including 24 after unwitnessed falls). Blood (obtained either at autopsy or on hospital admission) was sent for toxicological analysis on 28 patients where alcohol was suspected as being implicated in causing the fall. In 20 cases, blood alcohol levels exceeded 80 mg/dl, the current legal limit for driving in the U.K. (Fig. 2).

Scoring according to the Abbreviated Injury Scale (1990 revision) yielded injury severity scores ranging from 5 to 75, with a median of 25 (as shown in Fig. 3). The four individuals who had injury severity scores of less than 15 were found dead at the scene. Four of those who died had injuries acknowledged to be unsurvivable (ISS = 75). The body regions responsible for the maximum Abbreviated Injury Scale scores (MAIS) are shown in Table 1. Injury to the brain and/or spinal cord was responsible for the vast majority of the most severe injuries. In 47 cases, a single body region was

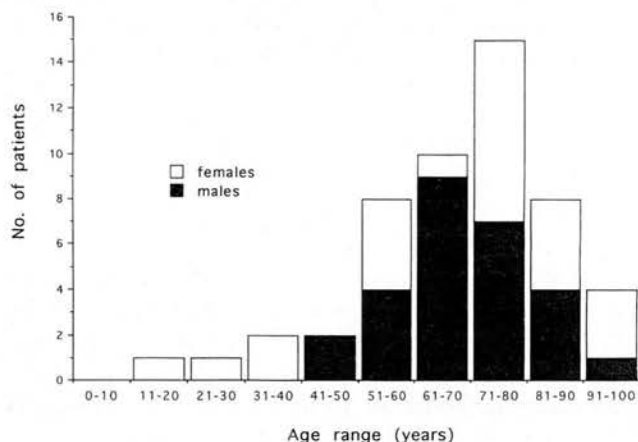


Fig. 1. Age and sex distribution.

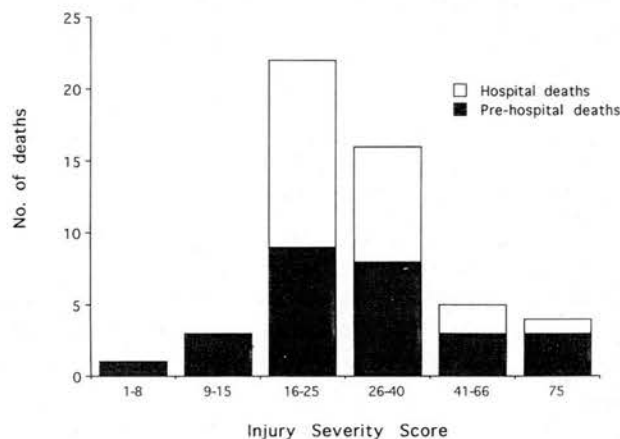


Fig. 3. Injury severity scores.

Table 1
Injuries responsible for maximum Abbreviated Injury Scale

Injury	Number of times responsible for MAIS
Brain/brainstem injury	35
Cervical spinal cord injury	8
Rib fractures with flail segment	6
Rib fractures without flail or internal injury	3
Liver injury	2
Rib fractures with massive haemothorax	1

responsible for MAIS; in four cases, two body regions were responsible.

4. Discussion

Roads are often considered to be places of potential danger: every year there are thousands of deaths on the roads in the U.K. [18]. In contrast, the familiarity of the home environment may result in a false perception of safety, but the results of this study demonstrate that amongst the potential dangers of many homes, are stairs. The problem of deaths following falls down stairs may be approached in a variety of ways. It is recognised that optimising stair design (including ensuring step-to-step uniformity) can minimise the risk of an accident [19]. The most obvious long-term way of reducing the danger of falls on stairs would be to standardise their design in new buildings.

Although fatal falls down stairs are uncommon in the young, they are a particular problem of the elderly. The potential causes of falls is varied and includes one or more of the following: simple trips and slips, impaired balance, incoordination and immobility, postural hypotension (particularly secondary to medication), arrhythmias, cerebrovascular events and the effects of alcohol. In this study, in a large number of cases involving the elderly where alcohol was not implicated, the cause of the fall was unclear. This is because many individuals were unable to provide an account of what had happened, having been found dead at the scene after unwitnessed falls.

It is of concern that many elderly individuals had unwitnessed falls down stairs within their own homes and were then unable to summon help, thereafter succumbing to injuries which were eminently treatable. In keeping with falls in the elderly in general, there may be a sound economic argument to devote more resources to prevention of falls down stairs [20]. Accidents might be prevented by targeting the socially isolated at-risk elderly population and making the stairs at home safer (e.g. by improving or adding handrails or by ensuring stair carpets are non-slip and well fixed). In some circumstances, following a home

assessment and consideration by a multidisciplinary trained team (comprising doctors, nurses, occupational therapists and social workers) [21], it may be appropriate to consider moving some elderly people to a safer home environment without stairs. It seems inevitable that whilst elderly people continue to live with stairs in their homes, accidents will continue to occur. Those at risk might also benefit from alarms which are designed to activate after falls, thereby allowing earlier emergency treatment in the event of a fall.

Alcohol has been implicated in contributing in some way in many forms of trauma and death, both in the U.K. and elsewhere [22–25]. Alcohol was heavily implicated in causing many of the falls. In this situation, the combination of increasing age (with attendant mobility problems) and acute alcohol intoxication renders stairs very dangerous. Having contributed to causing falls, acute alcohol intoxication may have rendered individuals prone to more serious injuries, by adversely affecting any natural tendency to protect themselves as they landed. In addition, chronic alcohol abuse (with associated liver disease) may also have predisposed to increased bleeding after injury. In this fashion, a relatively minor traumatic insult may have been transformed into a life-threatening problem.

The fact that the majority of deaths occurred in the pre-hospital setting may be more a reflection of the fact that many of those injured in the falls were alone and unable to summon help (because of pre-existing mobility problems, other medical problems and/or the effects of alcohol), than solely as a result of the severity of their injuries. Indeed, only four individuals (7.8%) had injuries recognised as being incompatible with life (injury severity score = 75). This contrasts with those who died following other forms of trauma, where a significant proportion have injuries recognised to be untreatable [26, 27].

Given that there may be a tendency for an unsteady person on the stairs to topple head-first downstairs during a fall, it is perhaps unsurprising that injury to the head and neck was responsible for the most severe injuries in the majority of patients. These head injuries, even if only relatively minor, may in the presence of alcohol intoxication or pre-existing mobility/medical problems have effectively prevented an injured person to obtain assistance after an unwitnessed fall. In addition, it has been suggested that the combination of acute alcohol intoxication and minor head injury may occasionally result in sudden death, perhaps by a direct effect on the brainstem cardio-respiratory centres [28]. This perhaps partly explains the deaths after injuries which might not ordinarily be considered to be life-threatening. Another important factor is that the elderly have a much higher risk of death after a relatively minor injury because of reduced physiologi-

cal reserve [29]. This appears to be particularly true in extreme old age (more than 80 years) [30].

Analysis of the pattern and severity of injuries amongst those who died after falling down stairs did not reveal any obvious potential for injury reduction measures targeted at specific injuries. The approach recently proposed to reduce the risk of hip fracture in the elderly by using hip padding to soften the "landing surface" in the event of a simple fall, does not extrapolate well as far as falls down stairs are concerned [31]. Apart from removing any obvious obstacles on the stairs which might cause additional injury in the event of a fall, attempts to make the surface landed upon safer are unlikely to be helpful. Instead, efforts would be better directed at trying to prevent falls occurring in the first place, as outlined above.

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The association between seniority of Accident and Emergency doctor and outcome following trauma

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Abstract

The actual survival of patients treated following trauma in four Scottish Teaching hospitals during five years was compared with predicted survival according to TRISS analysis. The data were analysed according to the seniority of the Accident and Emergency (A&E) doctor treating each patient. The group of patients treated by a consultant had a significantly better outcome ($p < 0.05$) than the group of patients treated by junior doctors. Analysis of outcome according to the grade of junior A&E doctor suggested a step-wise improvement in outcome with seniority, thus supporting the concept that an improved outcome is associated with experience and seniority. These results support calls for A&E consultants to be increasingly involved in the management of patients with major trauma. Such increased involvement would require an increase in the number of A&E consultants. © 1999 Elsevier Science Ltd. All rights reserved.

1. Introduction

Deficiencies in the management of patients with trauma in the UK have been well publicised and highlighted [1-3]. Retrospective review of 1000 deaths after trauma by the Royal College of Surgeons of England concluded that some deaths were unnecessary and that many were associated with delivery of emergency care by inexperienced doctors [1]. These conclusions were based upon subjective retrospective analysis of case notes, objective evidence based upon prospective data regarding the importance of experience of the resuscitating team is somewhat lacking.

The focus regarding the initial reception and resuscitation of the injured patient has naturally fallen upon the senior doctor (or resuscitating 'team leader') in the Accident and Emergency (A&E) department. As a result, some hospitals in the UK have dramatically altered their A&E staffing levels and work patterns in

order to increase the immediate availability of experienced doctors to manage seriously injured patients [4]. Unfortunately, attempting to elucidate the effect of the presence of senior staff within such hospitals is difficult [5,6]. Comparing patients' outcomes with those in other hospitals yields information about the effectiveness of different systems of care within two different hospitals, which may be influenced by numerous other factors apart from differences in seniority of accident and emergency staff [5,6]. In order to try to investigate the way in which the level of seniority of accident and emergency (A&E) doctor influences outcome after trauma, different cohorts of patients treated within the same hospitals need to be compared.

2. Patients and methods

The trauma care delivered in four Scottish hospitals (Edinburgh Royal Infirmary, Aberdeen Royal Infirmary, Glasgow Western Infirmary and Glasgow Royal Infirmary) was studied prospectively by the Scottish Trauma Audit Group between February 1992

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and December 1996. Criteria for inclusion in the study were those used previously by the Major Trauma Outcome Study, which specifically exclude children aged less than 13 years and elderly patients with isolated (osteoporotic) neck of femur fractures or isolated fractures of the pubic rami [3]. Data collected included the physiological state of 10968 patients at hospital presentation, together with the anatomical injuries sustained, from which Revised Trauma Scores and Injury Severity Scores were derived, respectively [7–9]. These scores enabled individual probabilities of survival to be calculated using TRISS methodology [10]. Analysis of actual deaths against expected deaths in the form of a *W*-Statistic allowed the management of different cohorts of patients to be compared [10]. Continuous, non-normally distributed variables were analysed using the Mann–Whitney *U*-test. Categorical variables were analysed using the chi squared test. The data capture rate for the study was 94%. Complete physiological data were available for all patients. All those who died as a result of their injuries were included.

Details of the most senior A&E doctor involved in treating each patient who presented following trauma were prospectively collected. This allowed all patients to be classified according to whether or not an A&E consultant had been involved in their management at any stage in the A&E department. The accuracy of the data collected was checked daily in each hospital by independent local staff employed by the Scottish Trauma Audit Group.

3. Results

The 1208 patients treated by an A&E consultant had a significantly better outcome than the 9195 patients treated by junior staff (Fig. 1). Although significantly ($p < 0.01$) more patients seen by a consult-

ant presented to A&E during 'normal' working hours (Monday–Friday, 9 a.m.–5 p.m.), analysis of outcome according to time of presentation revealed that the difference in outcome associated with consultant presence was more exaggerated outside than during 'normal working hours' (Fig. 2). Further analysis of outcome according to grade of junior doctor is shown in Fig. 3.

There was no significant difference in the pre-hospital times (time ambulance called to time arrived in hospital) between the consultant group (mean pre-hospital time 50 min) and the non-consultant group (median pre-hospital time 51 min). The patient group treated by consultants was significantly ($p < 0.01$) younger and significantly different in that it comprised more males, more patients who had suffered a road accident or high fall and fewer who had had a low fall or sporting accident. Injury Severity Scores in the consultant group were significantly higher, Revised Trauma Scores and probabilities of survival significantly lower. Overall, significantly fewer patients ($p < 0.01$) spent more than 2 h in the Accident and Emergency department. This finding was true even allowing for differences in severity of trauma; of those 1427 patients with major trauma (ISS > 15), the 503 patients treated by a consultant had a median time in A&E of 100 min, compared with 128 min for the non-consultant group ($p < 0.05$). In addition, patients with major trauma treated by a consultant were significantly more likely ($p < 0.01$) to have involvement of consultants from other specialties (including intensive care, general and orthopaedic surgery) than those patients not treated by an A&E consultant (28% compared with 13%, respectively). Similarly, a significantly higher proportion ($p < 0.01$) of patients with major trauma treated by an A&E consultant were transferred to the Intensive Care Unit, compared with those not treated by an A&E consultant (55% compared with 40%, respectively).

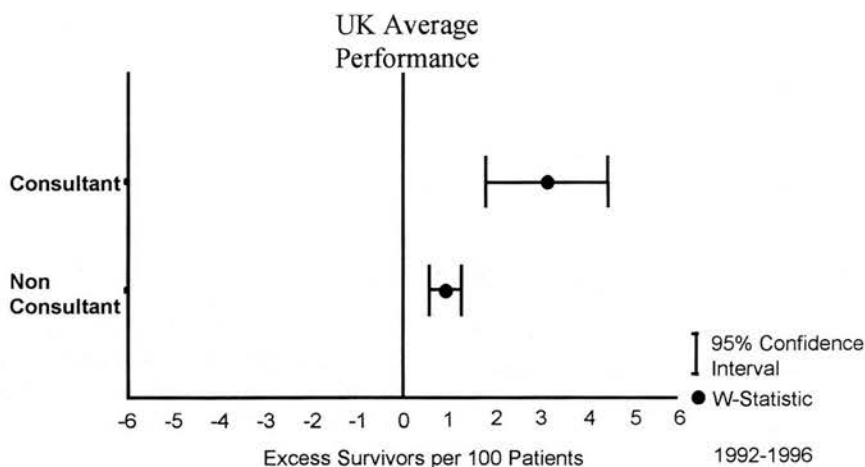


Fig. 1. Excess survivors per 100 patients by grade of A&E doctor compared to UK norm.

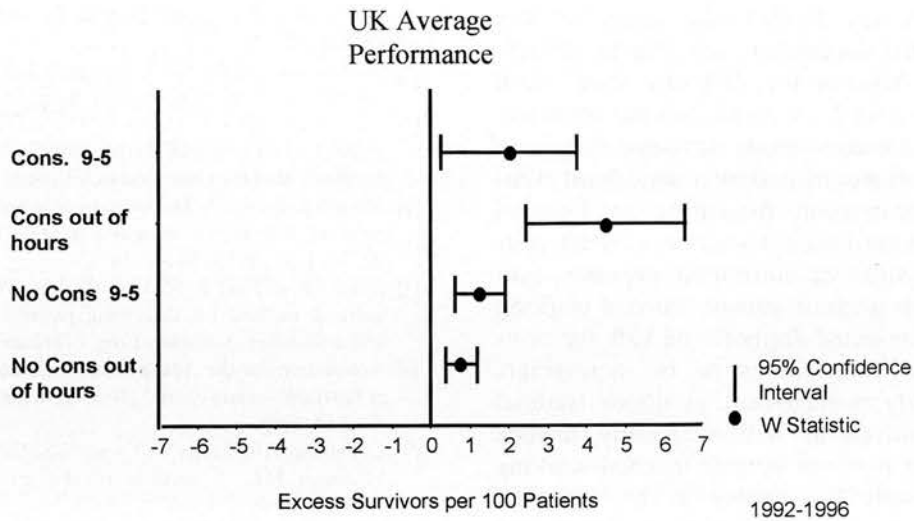


Fig. 2. Outcome by grade of A&E doctor and time of day.

4. Discussion

The organisation of trauma services in the UK remains controversial [5, 6, 11-14]. There have been calls for every hospital which manages seriously injured patients to install trauma teams comprising experienced doctors [15-17]. Improved outcome might be intuitively anticipated when patients with potentially life threatening emergencies are managed by trained and experienced doctors, but proving this is not easy. A randomised controlled trial of treatment by A&E consultants against junior doctors would not be feasible, for both logistical and ethical reasons. Similarly, a simple comparison of crude mortality rates of patients treated by consultants with those of patients treated by junior doctors would be misleading, since it takes no account of type and severity of injury, physiological derangement and age of the patient. TRISS methodology was developed using multivariate statisti-

cal techniques which take account of confounding factors [10]. It is validated and widely used and offers an opportunity to compare the management of different groups of injured patients [3, 10, 18].

The results of this study demonstrate that treatment of injured patients is associated with a better outcome when A&E consultants are involved in the initial management, rather than junior staff. Interestingly, the data support the concept that the training programme of junior doctors results in a gradual improvement in terms of patient care, as shown by the step-wise increase in outcome by grade of doctor.

The possible ways in which consultants might improve outcome are many and include more accurate diagnosis, greater early involvement of other senior specialists, more rapid transit time in accident and emergency, more liberal use of complex investigations and greater involvement of Intensive Care. Teasing out the relative contributions of each of these factors, if

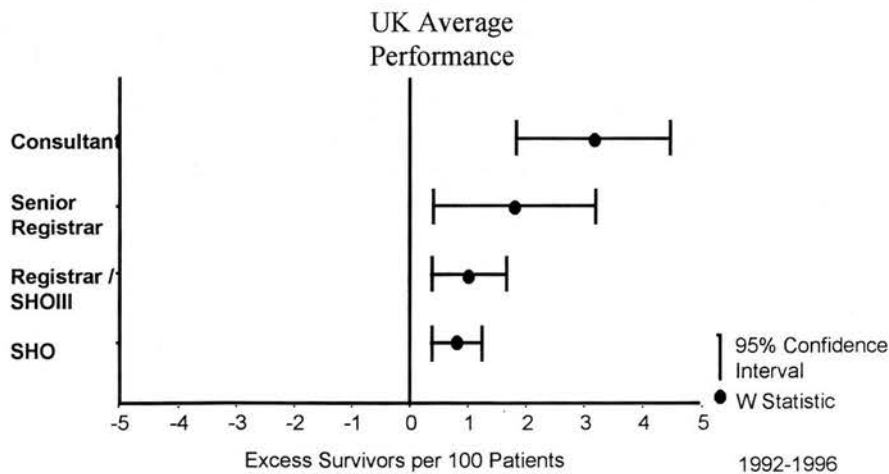


Fig. 3. Outcome by grade of A&E doctor.

any, would be extremely difficult. The results of this study do suggest that consultants are able to resuscitate and transfer patients for definitive care more rapidly than junior doctors. Considering the relatively small number of A&E consultants, it is not surprising that the group of patients treated by a consultant comprised a higher proportion presenting to hospital during normal working hours. However, it is interesting that the association of consultant presence with improved outcome is greatest outside 'normal working hours'. The data presented support the call for accident and emergency consultants to be increasingly involved in the early management of major trauma. This increased involvement will necessarily include increased consultant presence outside 'normal working hours'. This will only be feasible if the proposed expansion of the consultant grade in accident and emergency medicine is actually put into practice [19].

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Resuscitation of drowning victims in south-east Scotland

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Abstract

Introduction: Immersion in cold water is compatible with long-term survival, even when the period of immersion is relatively long. Guidelines for resuscitation after immersion stress the importance of prolonged resuscitation using advanced life support techniques. **Methods:** Deaths due to drowning in south-east Scotland between 1991 and 1997 were reviewed, using a variety of data sources. **Results:** 95 deaths (69 males, 26 females) from drowning occurred in the following sites: sea, 35; bath, 15; flowing freshwater, 26; still freshwater, 19. 22 (23%) of the drowning incidents were witnessed, 73 (77%) were unwitnessed. 28 individuals were recovered within 1 h of being seen alive, 13 having had witnessed accidents, 15 having had unwitnessed accidents. Six individuals were not resuscitated at the scene by the emergency services, despite being last seen alive within the previous hour. A further five individuals were initially resuscitated, but declared dead at the scene within 1 h of being known to be alive. **Conclusions:** Members of the emergency services, are failing to both initiate prehospital resuscitation and to continue this to hospital for victims of near drowning. There appears to be potential to reduce the drowning death rate by improving resuscitation. The emergency services and the public should be educated about the need to resuscitate those found in water. © 1999 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Resuscitation; Near drowning

1. Introduction

Drowning is a significant cause of death from trauma in south-east Scotland [1,2]. The most obvious way to reduce the death rate would be to prevent the drowning accident or incident. An additional way would be to improve the rate of successful resuscitation after a near drowning incident. It has been recognised for many years that cold water submersion is compatible with long-term survival, even when the period of immersion is relatively long [3–10]. As a result, guidelines for resuscitation of individuals who are found immersed in water stress the importance of prolonged resuscitation using advanced life support techniques [5,11–16]. This study examines the ex-

tent to which those individuals who died following drowning in south-east Scotland were resuscitated.

2. Methods

All deaths due to drowning in Lothian and Borders regions of south-east Scotland (as elsewhere in Scotland) are investigated by the Procurator Fiscal. In every case, forensic pathologists in the Forensic Medicine Unit are instructed to perform an autopsy and police officers are instructed to make enquiries in order to produce a detailed report. The circumstances of deaths due to drowning in this part of Scotland during the 7 years 1991–1997 were studied. A variety of data sources were used, including: Procurator Fiscal records, autopsy reports prepared by the Forensic Medicine Unit, police, ambulance and hospital records.

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Table 1
Resuscitation of the 95 drowning victims in Lothian and Borders, 1991–1997

<i>Individuals known to be alive within 1 h prior to being found</i>	
No resuscitation at scene, not taken to hospital	6
Resuscitated initially at scene, declared dead within 1 h at scene	5
Resuscitated initially at scene, taken to hospital for further resuscitation	17
<i>Individuals not known to be alive within 1 h prior to being found</i>	
No resuscitation at scene, not taken to hospital	57
Resuscitated initially at scene, declared dead within 1 h at scene	6
Resuscitated initially at scene, taken to hospital for further resuscitation	4

3. Results

There were 95 deaths (69 males, 26 females) from drowning amongst people aged between 5 months and 87 years. Considering that the population studied was 0.83 million, the rate of drownings per year was 1.6 per 100,000 [17]. The drownings occurred in the following sites: sea, 35; bath, 15; flowing freshwater (rivers, streams), 26; still freshwater (reservoirs, lochs, canals, ponds), 19. 22 (23%) of the drowning incidents were witnessed, 73 (77%) were unwitnessed.

The bodies of 28 individuals were recovered within 1 h of them having been last seen alive, 13 having had witnessed accidents, 15 having had unwitnessed accidents (Table 1). 11 of these 28 individuals were either never resuscitated or were declared dead at the scene, despite being known to be alive within the past 1 h.

Six individuals (mean age 50 years) were not resuscitated at the scene by the police or other emergency services, despite being known to be alive within the previous hour (Table 2). A further

five individuals (mean age 38 years) were initially resuscitated by police and/or ambulance crews, but were declared dead by a doctor at the scene within 1 h of last being known to be alive. None of these five patients benefited from doctor-led advanced life support or rewarming techniques (Table 3).

4. Discussion

The rate of drowning deaths was 1.6 per 100,000 per year in south-east Scotland—less than that in many other countries [18,19]. The pattern of deaths from drowning in south-east Scotland is different from that in other parts of the world [18–20]: the climate and low sea temperatures do not encourage outdoor recreational swimming. This is reflected in this study in that there were no deaths in relatively warm water of private swimming pools, but there were many in various outdoor waters, where the cold temperatures may have offered the submerged victims a degree of cerebral protection.

The majority of those who died of drowning in south-east Scotland received no form of resuscitation when found. In many cases, this appears to have been entirely appropriate, particularly where a body had been recovered having been immersed in water for several hours or days. However, it is a cause for some concern that six individuals received no resuscitation, despite the fact that the immersion incident resulting in drowning occurred only recently. It is also worrying that five individuals who did initially receive basic life support at the scene after a recent drowning incident, were declared dead by a doctor at the scene within 1 h of that incident, without receiving the potential benefits of either advanced life support techniques or a prolonged attempt at resuscitation. In the

Table 2
Details of the six individuals who were never resuscitated, despite being found within 1 h of last being alive

No.	Age (years)	Sex	Immersion witnessed?	Location	Time last seen alive (min)
1	47	M	Witnessed	Reservoir	15
2	21	M	Unwitnessed	Sea	25
3	47	M	Witnessed	Sea	40
4	55	F	Unwitnessed	Sea	40
5	59	F	Unwitnessed	Canal	45
6	71	M	Unwitnessed	River	50

Table 3

Details of the five individuals who were initially resuscitated, but declared dead at the scene within 1 h of being alive

No.	Age (years)	Sex	Immersion witnessed?	Location	Time last seen alive (min)
1	74	F	Unwitnessed	Bath tub ^a	41
2	19	M	Witnessed	Sea	42
3	27	M	Witnessed	Sea	42
4	16	F	Unwitnessed	Bath tub ^a	44
5	56	M	Witnessed	Sea	56

^a Water temperature at the time of submersion unknown.

cases of those individuals whose accidents occurred in the sea or rivers, the resuscitation attempt may have usefully included an attempt at core rewarming [6,16,21,22].

The data presented in this study demonstrate that members of the emergency services, including doctors, are failing to both initiate prehospital resuscitation and to continue this to hospital for victims of near drowning. These results suggest that there may be some potential to reduce the death rate from drownings in south-east Scotland by improving resuscitation. Police officers, other members of the emergency services and the public should be educated about the need to commence basic life support on a body found in water when there is a possibility of a recent drowning incident. Similarly, doctors (particularly general practitioners) attending the scenes of such incidents need to be aware of the potential benefit of prolonged resuscitation and hospital-based advanced life support resuscitation measures [5,11–16].

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Injury analyses of fatal motorcycle collisions in south-east Scotland

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Abstract

The timing of death and pathological findings in fatal motorcycle accidents in south-east Scotland between 1987 and 1997 were investigated. Of the 59 motorcyclists who died, 38 were dead when found at the accident scene, six others were alive when found but died at the scene, two died in an ambulance in transit to hospital and 13 died after reaching hospital. Scoring of the injuries according to the Abbreviated Injury Scale revealed Injury Severity Scores (ISS) ranging from 25 to 75. Overall, injuries to the head, neck and chest were responsible for the most severe injuries. Twenty-five motorcyclists had injuries acknowledged to be unsurvivable (ISS=75), most of which involved the thoracic aorta, brainstem and cervical spinal cord. The greatest potential to reduce the death rate amongst motorcyclists lies with accident prevention/injury reduction measures, rather than through improved treatment of injuries. Efforts to try to alter driving behaviour and to improve the design of vehicles and helmets need to continue. © 1999 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Motorcycle; Road accident; Death

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1. Introduction

Travel by motorcycle in the United Kingdom is associated with much higher rates of injury and death than those associated with travel by car, bus, lorry and bicycle [1]. In order to help determine which measures which are most likely to be effective in preventing death following motorcycle accidents, it is necessary to examine the nature and severity of injuries sustained by motorcyclists. In addition, an examination of the treatment provided and the timing of death allows conclusions to be drawn regarding the potential to 'save lives' by improving prehospital and hospital treatment.

2. Methods

All those individuals who died as a result of motorcycle accidents within Lothian and Borders regions of south-east Scotland between 1987 and 1997 were identified from records held by the Registrar for Births, Deaths and Marriages, the Procurator Fiscal, the Forensic Medicine Unit of the University of Edinburgh and the Scottish Trauma Audit Group (a government-funded organisation dedicated to the prospective collection of data on injured patients). In keeping with the policy of the Procurator Fiscal (an independent legal official with 'common law' jurisdiction on sudden unexpected deaths) to investigate road accident deaths, all those who died underwent post-mortem examination by the Forensic Medicine Unit of the University of Edinburgh. Analysis of the detailed description of the injuries recorded in the autopsy reports allowed each injury to be scored according to the Abbreviated Injury Scale (1990 revision), thus enabling Injury Severity Scores (ISS) to be calculated [2–5].

Scrutiny of ambulance, police and hospital records, together with data held by the Scottish Trauma Audit Group, allowed an insight into the treatment provided to those motorcyclists who were not killed immediately during the accident [6]. These data sources also yielded the timing of the deaths.

3. Results

3.1. Number and timing of deaths

During the eleven years under consideration there were 59 deaths, comprising 51 motorcyclists, seven pillion passengers and one side-car passenger. Fifty-eight of the 59 who died were wearing a helmet at the time of the accident. The majority of deaths occurred at the scene of the accident, with only 12 individuals reaching hospital alive (Table 1).

3.2. Injury scoring

Scoring according to the 1990 revision of the Abbreviated Injury Scale (AIS) yielded Injury Severity Scores (ISS) ranging from 25–75 (Table 2). Twenty-five individuals had

Table 1
Place of death

Place of death	Number
Died at accident scene-found dead	39
Died at accident scene-found alive	6
Died in transit to hospital	2
Died in hospital	12

Table 2
Injury severity scores according to place of death

ISS	Prehospital death	Hospital death	Total
1–15	0	0	0
16–25	1	0	1
26–40	9	5	14
41–66	12	7	19
75	25	0	25

injuries acknowledged to be unsurvivable (AIS=6, ISS=75), all of whom died at the accident scene. The 25 patients with unsurvivable injuries had a total of 30 injuries which are currently considered untreatable (three patients had sustained more than one unsurvivable injury). These 30 injuries predominantly involved the thoracic part of the aorta, the brainstem and high cervical spinal cord (Table 3).

3.2.1. Maximum abbreviated injury scale scores

Analysis of injuries according to which body regions were responsible for the most severe injuries sustained by each individual is acknowledged to be useful in motor

Table 3
Unsurvivable injuries described in detail

Body region	Injury	Number
Head and neck	Transection of upper cervical cord	4
	Skull fracture with brainstem laceration or massive crush	5
	Fracture/dislocation at atlanto-occipital joint with brainstem laceration or massive crush	4
	Complete decapitation	1
Chest	Transection of thoracic aorta at junction between arch and descending portion	10
	Transection of ascending aorta	1
	Ruptured left ventricle	3
Abdomen	Massive liver destruction	2

Table 4
MAIS scores according to body region

AIS body region	Number of times responsible for MAIS
Head and neck	38
Chest	28
Abdomen	10
Extremities	3
Face	0
External	0

vehicle injury research [2]. AIS scoring of all the injuries revealed maximum AIS (MAIS) scores for all those who died. Four of the six possible AIS 'body regions' were responsible for MAIS scores, but in keeping with the pattern of unsurvivable injuries overall, the MAIS scores were found predominantly within the body regions of 'head and neck' and 'chest' (Table 4).

4. Discussion

Analysis of the timing of deaths revealed that most of the deaths of motorcyclists after road traffic collisions occurred before they reached hospital. It therefore follows that the potential to reduce the death rate amongst motorcyclists in south-east Scotland by improving hospital treatment appears to be somewhat limited. Further evidence supporting this conclusion is that no motorcyclist died in hospital with only minor injuries — all had an ISS of at least 26 (an ISS of greater than 15 being an accepted definition of 'major trauma', with an associated mortality of at least 10% [6]). Furthermore, analysis of the quality of care given to patients with major injuries in south-east Scotland (measured in terms of actual survival compared with expected survival using prospectively collected data in TRISS analysis) revealed that this region compares favourably with other parts of the United Kingdom [7–10].

The prehospital deaths can be divided up into those motorcyclists who were found dead, those who were found alive but died at the scene and those who died in transit to hospital. The results demonstrate that the majority of those who died before reaching hospital were dead when found. This means that there appears to be limited potential to significantly reduce the death rate by improving prehospital medical attention. Findings of previous studies have been conflicting as to whether or not lives could be saved in severely injured victims by simple airway opening manoeuvres (e.g. jaw thrust manoeuvre, manual removal of debris from the oropharynx, use of the recovery position) being performed by a member of the public without equipment at the accident scene [11,12]. Certainly, in this study none of the individuals appeared to have died as a result of simple airway obstruction which would have been amenable to straightforward airway opening manoeuvres.

Twenty-five motorcyclists (42%) had sustained injuries which are acknowledged to be unsurvivable (AIS=6, ISS=75). The most common unsurvivable injury involved complete transection of the thoracic aorta. Although some debate remains about the

exact pathophysiological mechanism responsible for this lesion, with various different theories proposed, this injury is invariably associated with rapid deceleration and the application of a large amount of blunt force [13–16]. Despite the fact that all except one motorcyclist were wearing specially designed protective helmets, unsurvivable injuries to the brain, brainstem and upper cervical spinal cord occurred on 14 occasions. Similarly, despite helmet use, the head and neck was the most severely injured region in those motorcyclists who died with potentially survivable injuries (ISS <75).

The results of this study tend to point towards better accident prevention/injury reduction as the principal way forward to reduce the death rate amongst motorcyclists, rather than through improvements in hospital treatment. Measures designed to prevent accidents will be most effective if they are successful in permanently altering the driving behaviour of both motorcyclists and other road users.

Improvements in motorcycling equipment (helmets, clothing) and motor vehicle design may be successful in reducing the severity of injuries sustained by motorcyclists. The design of certain motorcycles has been implicated in causing specific serious injuries (e.g. large petrol tanks causing perineal injuries) [17,18]. It is possible that the future design of motorbikes may assist with a significant reduction injuries sustained in a collision. Examples are the addition of leg protectors and air bags [19,20]. Air bags incorporated into the top of a petrol tank would aim to alter the trajectory of a motorcyclist in the event of a collision, with the aim of enabling the motorcyclist to be thrown over the top of the vehicle it had collided with, rather than into the side of it. Such a modification would be most useful in the event of a head-on collision. Similarly, it is possible that future modifications of the design of cars and other vehicles might render them more 'friendly' to the motorcyclist in the event of a collision. The general scope of such developments would be to make the exterior of cars less unyielding when hit, thereby lessening the very rapid deceleration which appears to be an important factor in causing many of the serious and life-threatening injuries to motorcyclists. This philosophy has already been strongly advocated as a way of reducing injuries to pedestrians struck by cars [21].

Injuries to the head and neck continue to be responsible for a large proportion of the fatal injuries, despite the widespread use of appropriate helmets. It is therefore not surprising that attention will continue to be focused upon continuing use of helmets and further improvements in helmet design [20,22]. Although it is likely that there will be future modifications in both construction materials and design, it is difficult to see how some of the most severe injuries might be prevented in the event of an accident, considering the tremendous forces involved in very rapid deceleration from high speed. Accident prevention and injury reduction measures are clearly of great importance, yet it seems that the inherent vulnerability of motorcyclists almost inevitably predisposes them to a greater risk of injury in the event of an accident than a properly restrained car driver travelling at an equivalent speed.

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ORIGINAL COMMUNICATION

Suicidal high falls

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SUMMARY. There are few data on committing suicide by jumping from a height. Information on suicidal high falls in southeast Scotland was prospectively gathered over 7 years (1992–1998). Data sources included ambulance, police, hospital and forensic records. Injuries sustained were scored according to the Abbreviated Injury Scale, generating Injury Severity Scores (ISS).

Sixty-three individuals (50 males), appeared to have committed suicide by falling from a height. The backgrounds were diverse, but 44 individuals had known previous psychiatric illness, 18 having attempted suicide before. The most common locations were high bridges, with two accounting for 23 deaths (37%). Only nine individuals (14%) reached hospital alive. ISS range was 16–75, including 22 scores of 75. These individuals had a total of 24 injuries acknowledged to be unsurvivable, comprising 10 thoracic aortic ruptures, eight massive brain/brainstem injuries, four cardiac injuries, and two high spinal cord transections.

The high rate of prehospital death reflects the heights of the falls and consequent major injuries. Prevention of suicide is acknowledged to be difficult – these results suggest that hospital treatment of injuries sustained has little to offer in terms of reducing the death rate from suicidal high falls. © APS/Harcourt Publishers Ltd 2000

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INTRODUCTION

The potential risk of serious injury and death resulting from a fall from a height has been recognized for thousands of years.¹ In more modern times, studies have demonstrated that the risk of death following a high fall depends to a large extent upon the distance fallen, although other factors such as the age of the victim, the position of the body on landing and the surface landed upon can play a considerable part.^{2–6} However, despite the relatively soft landing and associated slow deceleration by a landing into water, the

experience gained from studying very high falls into water demonstrates that they are consistently associated with very serious injury.^{7,8}

The Abbreviated Injury Scale (AIS), initially developed and subsequently revised by the Association for the Advancement of Automotive Medicine, is a useful tool in forensic practice to classify each injury sustained.^{9–11} This system is useful also to analyse the pattern of injuries sustained, and by use of the derived Injury Severity Score (ISS), allows an objective score of the total injuries sustained by each individual.^{11,12} The correlation between height of fall and ISS is consistent enough to even allow some researchers to suggest that the ISS may play a useful role in helping to estimate the height fallen.^{5,13}

Most studies of high falls describe accidental causes and highlight the potential to prevent such accidents in certain groups (e.g. unsupervised young children near open windows, college students falling from balconies, construction workers, roofers, window cleaners).^{14–18} The use of a high fall as a means of committing suicide is also not new. In 1190, anti-Jewish riots were rife throughout England – as a result

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of one of these riots, dozens of Jews trapped in York Castle chose to jump from the top of Clifford's Tower to their deaths, rather than hand themselves over to the mob.¹⁹ Suicide is relatively common in the modern Western world – in the UK the government identified mental illness and associated suicide as one of the key areas worthy of attention in order to improve the nation's health.²⁰ Certain methods of suicide, such as poisoning and hanging, appear to be particularly frequent, but suicidal jumps appear to be less common.²¹ This study investigates the epidemiology of suicidal falls in southeast Scotland.

METHOD

Deaths following trauma in southeast Scotland were studied prospectively between 1992 and 1998 in a collaborative research study involving the Forensic Medicine Unit of the University of Edinburgh, the Scottish Trauma Audit Group and the Accident and Emergency Department of the Royal Infirmary of Edinburgh. Amongst the traumatic deaths, all deaths following high falls between 1992 and 1998 were identified, and the peri-mortem circumstances studied, enabling suicidal deaths to be identified.

Data sources included: detailed police reports, forensic medicine records and autopsy findings, ambulance records, hospital case notes and the database of the Scottish Trauma Audit Group. The principal source of the details of the circumstances came from the police reports, which were prepared upon the instructions of the Procurator Fiscal (the local legally competent investigator of deaths) and allowed an insight into how each incident happened. Deaths following falls which were down stairs or from a standing height only (i.e. less than 2 m) were excluded from the analysis.

Autopsies are performed by the Forensic Medicine Unit of the University of Edinburgh on all traumatic deaths in Lothian and Borders regions. The injuries sustained by all those who died after suicidal high falls were extracted from autopsy records and, where appropriate, from hospital case records. All injuries were scored according to the AIS (1990 revision), allowing an ISS to be generated for each person.^{9,11,12}

RESULTS

Sixty-three individuals (50 males, 13 females) appeared to have committed suicide by falling or jumping from a height during the 7 years of the study, which, considering the known population of 830 000, reflects a rate of suicidal falls of 1.1 deaths per

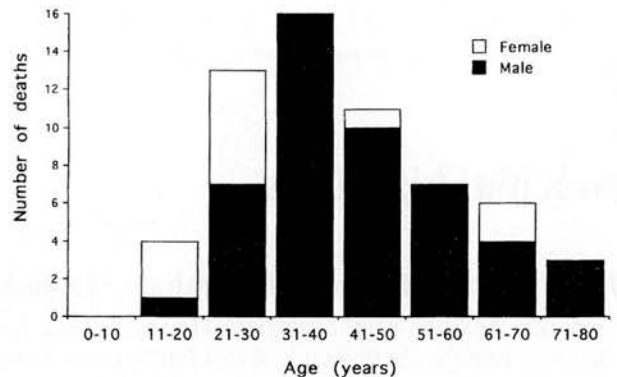


Fig. 1 High fall suicides by age and sex

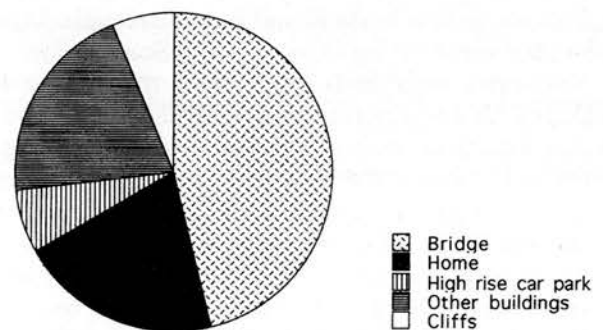


Fig. 2 Site of suicidal falls

Table 1 Apparent background to the suicides

Background	Number of deaths (n = 63)
Psychiatric illness	44
Relationship difficulties	6
Chronic illness	5
Alcohol-related problems	2
Unemployment	1
Unable to cope with partner's death	1
Unclear	4

100 000 per year.²² The age and gender of those who died is shown in Figure 1. The sites where the high falls occurred is shown in Figure 2: the two most frequent sites for suicidal falls were two bridges, which accounted for 23 deaths (36.5% of the total). One of these bridges is 180 ft high, the other is 80 ft high.

The background to the suicides appeared to be diverse. Analysis of the evidence implicated certain factors as being important in precipitating the suicide. These factors are shown in Table 1. Psychiatric illness appeared to be an important factor, with 44 individuals (70%) having been treated for psychiatric symptoms. Eighteen of those who died had previously

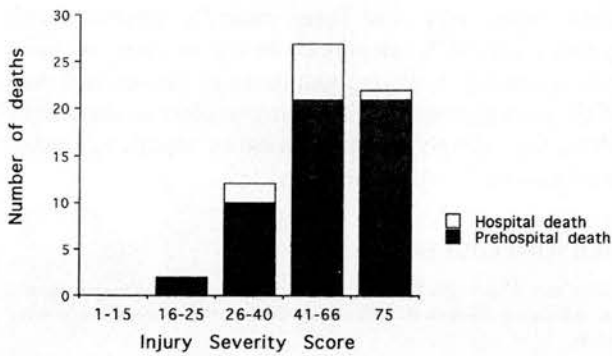


Fig. 3 Injury Severity Scores

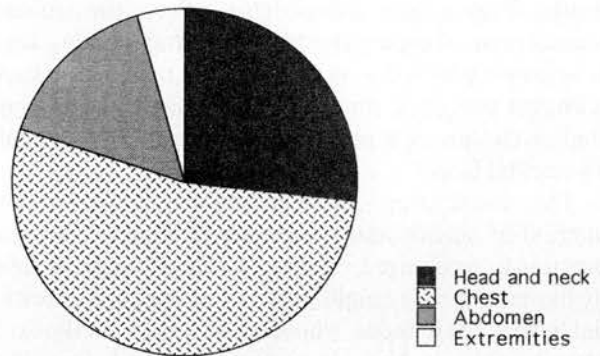


Fig. 4 Body regions responsible for MAIS.

Table 2 Unsurvivable injuries (AIS = 6)

Unsurvivable injury	Number of patients
Complete rupture thoracic aorta	10
Massive injury to brain/brainstem	8
Massive cardiac disruption	4
Transected upper cervical spinal cord	2

Includes four patients who had two separate unsurvivable injuries and one patient who had three separate unsurvivable injuries

attempted suicide, but only 13 told someone else that they were feeling suicidal prior to the fatal fall. Only six individuals left a suicide note.

Fifty-four individuals died at the scene of the fall, with all but two of these being dead when found. The remaining nine individuals survived to reach hospital alive, but died later of their injuries. Analysis of the injuries sustained revealed an ISS range of 16–75 (Fig. 3). Eighteen of the 22 individuals with an ISS of 75 had injuries acknowledged to be unsurvivable (Table 2). Five individuals had more than one unsurvivable injury. Analysis of the pattern of injuries for each individual allowed the most severely injured body region to be identified according to the AIS. The body regions responsible for maximum AIS (MAIS) for each patient are shown in Figure 4.

DISCUSSION

The scene of death after a high fall may understandably appear suspicious at first sight to investigating police officers who may, quite rightly, choose to involve the police surgeon (forensic medical examiner). Although a death may appear to be a suicide, the investigating professionals need to keep an open mind as homicide has been made to look like suicide in the past, particularly by bodies being thrown from a height after being killed. Examination of the scene

of death should include exact recording of where the body came to lie to rest and its position (in particular the horizontal distance away from the building/bridge or cliff edge), as this may provide later clues as to the height from which an individual fell, and whether or not he/she fell, jumped or ran and jumped.²³ It seems likely that the use of mathematical models and computer simulation will be developed sufficiently to assist with this.^{13,24} Later in the course of police investigations and autopsy, additional information may come to light which provides further clues as to the reason for the death. The pattern of injuries may enable a judgement as to whether an individual fell feet or head first.²⁵

This study has allowed an insight into suicidal falls (autokabalesis) in southeast Scotland. In keeping with previous studies from other parts of the world, the majority of those who died were male.^{8,26–29} The calculated rate of suicidal falls, representing less than one-tenth of the national rate of suicides, is likely to be an underestimate, since a number of other cases which might possibly have been suicides were not included in this study.²⁰ Analysis of the circumstances surrounding these cases did not enable a judgement to be made as to whether or not death was accidental or suicidal. Considering that in only a small proportion of the suicidal falls in the study a suicide note was left or someone had been told of the deceased's intention, it appears quite likely that a significant number of other deaths from falls were actually suicides. This contrasts with the situation with deaths from hanging, where it may be easier to reach a judgement as to whether or not the death was suicidal.²¹

Of the different ways in which suicidal individuals may try to end their lives, many are relatively non-violent and do not involve disfigurement – these include hanging, drug overdose, carbon-monoxide poisoning and plastic bag asphyxia (advocated by various groups interested in assisting 'self-deliverance').³⁰ The violence and disfigurement involved in

deaths from a high fall perhaps reflects the violent mental turmoil experienced by these individuals – this is in keeping with the fact that a high proportion had a known psychotic illness. Indeed, this proportion is similar to that in a previous study from Glasgow of 32 suicidal falls.²⁹

The association between choosing a violent method of suicide and severe mental illness has been previously recognized.^{26,31} Those who attempt suicide by jumping from a height appear to have greater suicidal intent than those who choose other methods.²⁸ Despite this, it has also been suggested that the method of suicide chosen depends simply upon availability.²⁷ Certainly in Edinburgh, the profusion of high buildings/bridges and relative unavailability of guns may partly influence the pattern of suicides.

The vast majority of suicidal falls resulted in death at the scene and most of these individuals were dead when found. It is thus clear that there is relatively little potential for improved hospital treatment to offer in terms of saving lives. This is confirmed by an analysis of the pattern of injuries – all had an ISS of more than 15 (the accepted definition of major trauma) and many had injuries acknowledged to be unsurvivable (AIS = 6).^{9–11} Indeed, all those who survived to hospital had an ISS of more than 25, again implying little potential for such lives to be saved by improving hospital treatment.

The heights of many of the falls and the recognized association between height of fall and severity of injury probably explains the large number of unsurvivable injuries (AIS = 6).⁵ These unsurvivable injuries principally involved the thoracic aorta, heart, brain and brainstem, which is in keeping with data from previous studies.²⁵ The most frequent unsurvivable injury was rupture of the thoracic aorta at the junction of the arch and the descending part, in keeping with the very rapid deceleration seen in other high energy impacts.³²

Having established that there seems little potential to reduce the death rate from suicidal falls by improving hospital treatment, it is worth considering whether some of the falls might have been prevented. Most of those who died had a past history of psychiatric problems, but these problems are relatively common amongst the general population, so do not present a small group of at-risk individuals to target. In any case, experts remain somewhat sceptical about being able to prevent suicide.³³ Only a small proportion of those who died appeared to have told someone about their suicidal intention, rendering prevention even more difficult. The sites chosen for the suicidal falls included two bridges which were used repeatedly (one in the city centre, the other on the outskirts of the city). As a result of the large numbers of suicides at

these sites, they have been recently targeted with notices and SOS telephones to try to avert suicides. Their efficacy, however, remains to be proven and even if they are successful in reducing suicides at these sites, there may simply be an increase in suicides at other sites and/or by other methods.

ACKNOWLEDGEMENT

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ORIGINAL COMMUNICATION

Early adolescent suicide: a comparative study

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SUMMARY. A study was undertaken of suicides in children and adolescents aged 16 years and under in South Australia, (Australia), and in San Diego County (USA) from January 1985 to December 1997. In South Australia there were 48 cases of youth suicide, representing 2% of the total number of 2251 suicides over that time. There were 34 males and 14 females (age range 13 to 16 years; mean = 15.3 years), with 22 hangings (46%), six gunshot wounds (13%), five train deaths (10%), four drug overdoses (8%), four jumping deaths (8%), three self immolations (6%), three carbon-monoxide inhalations (6%) and one electrocution (2%). In San Diego County there were 70 cases, representing 1.6% of the total number of 4492 suicides. There were 48 males and 22 females (age range 11 to 16 years; mean = 14.7 years), with 41 gunshot wounds (59%), 21 hangings (30%), six drug overdoses (9%), and two jumping deaths (3%). Preferred methods of suicide differed between the two areas, with significantly more gunshot suicides in San Diego compared to South Australia. The methods of suicide also differed in South Australia from older age groups, with more hangings, jumping deaths and self immolations, and fewer firearm and carbon monoxide inhalation deaths. Suicides in adolescents under the age of 17 years in both populations were, however, rare, with no demonstrable increase in numbers over the time of the study.
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INTRODUCTION

Youth suicide has been gaining increasing public attention in Australia and other countries, including the USA, with concerns being expressed that significant increases in numbers of these deaths were occurring.¹ The present study was undertaken to review the features of such deaths in a series of children and adolescents under the age of 17 years in Australia, and to compare them to a group of similar age from the USA.

MATERIALS AND METHODS

The files of the Forensic Science Centre, South Australia, and the Medical Examiner's Office, San Diego County, California, were searched for all cases registered as suicide in individuals under the age of 17 years, over a 13-year period from January 1985 to December 1997. The Forensic Science Centre provides autopsy services to the State Coroner for the state of South Australia, Australia, and the San Diego Medical Examiner's Office provides a similar service for the population of San Diego County, California.

It is recognized that a small number of certain types of fatalities that were classified as accidental, such as drownings and heroin overdoses, may have been suicides, and that other deaths, such as those involving fires and trains may have been suspicious. There may also be under-reporting of very young suicides. However, all cases in this study had undergone

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