A mixed-methods approach to the development and evaluation of trauma systems with particular reference to the regionalisation of trauma care in England – ‘matching system to situation’

A thesis submitted to the University of Manchester for the degree of Doctor of Philosophy in the Faculty of Biology, Medicine and Health

2018

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Abstract

Background: Trauma is a significant public health problem both in the UK and beyond. It can have a devastating impact on individuals, their family and society. The care of injured patients has long been thought to be sub-standard in the UK and patient outcomes were noted to be worse than other developed countries. Between 2010-12 regional trauma systems were introduced in England, with the aim of improving survival and long-term outcomes of injured patients. The aim of this study was to critically assess the implementation of these trauma systems on processes and outcomes of care in two regions of England.

Methods: A systematic review was undertaken to identify studies evaluating the association between an inclusive trauma system and patient outcome. A mixed-methods approach was used for the study. Data on trauma deaths were obtained from the UK Office for National Statistics (ONS). The Trauma Audit and Research Network (TARN) database was interrogated to provide data on all patients who presented to hospital within two years before and two years after trauma system implementation. A time-series analysis and a before and after study, using a comparator region to control for temporal trends, was undertaken for each region. Twenty semi-structured interviews with Emergency Department (ED) staff were conducted to gain a broader understanding of the effect of this change. Data were then merged and areas of convergence and discrepancy highlighted.

Results: The systematic review identified eight observational studies that all demonstrated a significant fall in the odds of death when patients presenting with traumatic injuries were treated within such a system. However, they were deemed to represent a very low-quality body of evidence. ONS data demonstrated that whilst trauma mortality rates were stable, between 30-50% die outside of hospital. Analysis of TARN data demonstrated that, following system implementation, a greater proportion of injured patients were seen at Major Trauma Centres (MTCs), quality of care indices such as time to CT scan improved and mortality fell. Analysis of the interviews revealed seven main themes and whilst all staff welcomed the commitment to improve trauma care, some, especially outside of the MTCs, expressed concerns about disengagement and being unable to provide the level of care expected.

Conclusions: This study adds to the body of evidence supporting the role of inclusive trauma systems in improving quality of care indices and patient outcomes. Contrary to some other studies, this study has shown improvements within two years, particularly at MTCs. Whilst most ED staff interviewed corroborated this view, some barriers to delivering high quality trauma care were felt to remain. Whilst trauma was once seen as a disease of young men and motor vehicle collisions, it is now dominated by falls in the elderly population and trauma systems must be able to meet their needs. Further research is warranted to learn more about the large population of trauma patients that do not survive to reach hospital. Perhaps some of the greatest future improvements of trauma systems are to be found here.
Declaration

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Dedication

To my parents
Acknowledgements

Firstly, I would like to thank my supervisors, Professor Chris Todd and Professor Fiona Lecky, who have been very generous in their support over the past few years. I would also like to thank the Royal College of Emergency Medicine and the board of the Trauma Audit and Research Network (TARN) for funding my studies.

Particular thanks must also go to Antoinette Edwards and Tom Lawrence of TARN, who provided support around the use of the TARN database and data extraction. I would also like to thank Dr Ben Windsor-Shellard of the UK Office for National Statistics who provided data on deaths from trauma.
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Chapter 1: Introduction
Trauma

*noun (plural traumas or traumata /-mətə/)*

1. A deeply distressing or disturbing experience

2. *[mass noun]* *Medicine* physical injury

System

*noun*

1. A set of things working together as parts of a mechanism or an interconnecting network; a complex whole

2. A set of principles or procedures according to which something is done; an organised scheme or method

*Oxford English Dictionary*, 2013
Traumatic injury inflicts a major toll on individuals, their families and society. It can affect any one at any time anywhere and has a multitude of causes including falls, motor vehicle collisions, burns and penetrating injuries such as stabbings. It can be accidental, self-inflicted or secondary to assault and can vary in its severity from a minor skin laceration to a catastrophic injury causing immediate death. Trauma is a leading global health problem affecting 135 million people a year and is responsible for around 5.8 million deaths annually.\(^1\) Around 50 million people world-wide are moderately or severely disabled due to injury and over 180 million disability-adjusted life years are lost annually.\(^2\) The global burden of disease due to trauma is expected to increase dramatically in the coming years, becoming the third leading cause of death by 2020.\(^2\)

Whilst low to middle income countries carry the greatest burden of death from trauma,\(^3\) in the UK, over 20,000 cases of major trauma occur each year with over 10,000 deaths.\(^4\) Due to the nature of the disease, many of those killed are young adults\(^4\) although there is evidence that more and more elderly people are sustaining serious injury.\(^5\) Whilst it has long been thought that major trauma in the UK is predominately secondary to motor vehicle collisions, a recent report by the UK Department of Transport showed a 44% reduction in fatalities in 2016 compared to 2006.\(^6\) In comparison, injuries and deaths from falls are increasing.\(^5\) Apart from causing death and disability, trauma also carries a huge financial cost. Beyond the estimated initial cost to the NHS of £300 - £400 million per year in providing treatment to trauma patients, lost economic output as a result of trauma in the UK is estimated to be between £3.3 to £3.7 billion per year.\(^7\)

Since the inception of the UK’s National Health Service (NHS) in 1947 until April 2012 (April 2010 in London), seriously injured patients in England have been routinely taken to the nearest hospital emergency department, regardless of whether this was an inner-city teaching hospital with 24-hour consultant presence, all surgical specialties on site and rapid access to imaging modalities, or a local hospital with few surgical specialties and a trauma team run by junior doctors. Patients may then have been required to be transferred to other hospitals to receive definitive care of their injuries after stabilisation, if they survived. Such inconsistency in the
management of trauma patients, depending on where in the country they were treated, has long been a matter of concern for many clinicians involved in delivering trauma care. Since the establishment of the UK Trauma Audit and Research Network (TARN) in 1990, it has demonstrated large variation in the mortality of trauma patients treated in different hospitals in England.8 There have also been multiple reports and studies calling for improvement in the care of the seriously injured in the UK since the 1960s.9,10 Whilst many injuries are preventable, it was also felt that there was unnecessary mortality from inadequate organisation and delivery of trauma services. Surely where you live should not determine if you live.

One report that perhaps led to the instigation of change was published in 2007 by the National Confidential Enquiry into Patient Outcome and Death.10 This report found suboptimal care in over 60% of injured patients included in its review. Following this, NHS England appointed a National Clinical Director for Trauma in 2008 with the remit of driving improvement in the quality of trauma care provision. A report published by the UK National Audit Office in 2010 provided further impetus for change after it demonstrated deficiencies in trauma care, and, making comparisons with outcomes in the USA, estimated that mortality for patients admitted with major trauma in England was 20% higher after adjustment for case-mix.7 Importantly, this report also recommended the implementation of regional trauma networks. Improving the care of the seriously injured seemed, at last, to become a Government priority and London was the first English region to introduce such a network in April 2010. A directive for change was then made explicit within the 2011 NHS Operating Framework requiring all other English NHS regions to implement a trauma system by April 2012.11

Evidence from other countries such as the United States of America (USA) and Australia, has shown that when trauma care within a population is reorganised into a system whereby the most seriously injured are treated at specialist centres that can offer definitive care, even if that means bypassing the nearest hospital, mortality and morbidity rates improve.12,13 The overriding principle here is that ‘the right patient should be treated in the right place at the right time.’ An example of this would be the transfer of a patient with a serious head injury directly from the
scene of an accident to a regional neuro-surgical centre where a neuro-surgeon can rapidly operate on the patient to remove life-threatening bleeding on the brain.

However, despite a broad national framework, each English NHS region was tasked with developing their own plan, based upon geography, transport times and taking account of the services that were able to be provided by their own network of hospitals. This led to the designation of three tiers of hospitals that provide trauma care; Major Trauma Centres (MTCs), Trauma Units (TUs) and local Emergency Hospitals. Patients who are recognised by pre-hospital care providers (e.g. paramedics) to be seriously injured and meet locally agreed criteria, such as physiological derangement or particular types of injury would be taken to a MTC if within a 45 minute drive, even if this meant bypassing another hospital (non-MTC) en-route. An exception to this would be if a patient had an acute airway obstruction or catastrophic, uncontrolled bleeding where they would be taken to a TU (if close by), stabilised then transferred expeditiously to the MTC for definitive care.

It is envisaged that by taking a seriously injured patient immediately to a MTC that they will receive more appropriate, definitive care to manage their injuries and improve their chance of survival and a ‘good’ outcome. Such a facility will usually be based in a university teaching hospital that offers consultant delivered care, most (if not all) surgical specialities to manage all types of injury, immediate access to operating theatres and radiological investigations such as Computerised Tomography (CT) and access to rehabilitation services from early on.

The role of the TU can be seen as something of a ‘staging post’ for those patients who are more than 45 minutes away from a MTC. The unit should be able to manage life-threatening conditions such as intra-abdominal bleeding, but may not be able to provide definitive care for all injury types, such as head or pelvic injuries. This may then necessitate the transfer of the patient to the MTC within the same ‘network.’ Local emergency hospitals provide general emergency cover to their local population but, when ambulances were once transporting seriously injured patients to their doors, this should now not be the case. However, every hospital, whatever its ‘formal’ trauma status must be prepared for any eventuality.
As of January 2018, there is a network of 27 MTC’s in England (Figure 1). Eleven provide care for adults and children, eleven provide care for adults only, and five provide care for children only. Two regions of England require special mention. In Greater London, trauma patients are taken to one of four MTC’s, whilst Greater Manchester developed a collaboration between three MTC’s as neither hospital was able to offer all required surgical specialties at one site. This collaboration has recently been reduced to two centres following the removal of MTC status from the University Hospital of South Manchester.

Over the past 10 years or so the ‘regionalisation’ of specialist health care provision has affected many parts of the NHS, not just trauma care. Reconfiguration of local services has meant that in most parts of the country, conditions such as stroke, myocardial infarction (heart attack) and vascular surgery are managed in specialist centres, sometimes far away from a patient’s nearest hospital and home. Since the introduction of the NHS, reconfiguration of clinical services has attracted public and political controversy. Financial and workforce constraints, now and in the future, suggest that the pressure to reconfigure services will continue to grow. The benefits to quality and patient outcome from a more centralised model of care have been well documented for other medical conditions\textsuperscript{14,15} and, in the following chapters, I will explore whether this has also been the case following the centralisation of trauma care in two regions of England.

I would now like to present the background to the concept of a trauma system, to describe the elements that are fundamental to its structure and to begin to understand some of the evidence base behind introducing such a system on a national scale.
Figure 1: Location of MTCs in England


Background: Major Trauma Centres and Trauma Systems

Whilst the vast majority of the trauma burden is borne by the civilian population, trauma care and, indeed, trauma systems owe much of their development to the theatre of war. During the American Civil War, military doctors realised the importance of evacuating casualties from the
battlefield and in the Vietnam War pre-hospital care and helicopter transfer to medical facilities helped improve survival even further.\textsuperscript{16} Such structures, along with improvements in trauma care such as the aggressive use of tourniquets, revised transfusion protocols for major haemorrhage and the development of ‘damage control’ surgery, are believed to have contributed to greatly improved outcomes in severely injured military personnel. In fact, a UK National Audit Office (NAO) report published in 2010 that highlighted the excellent care and outcomes of British soldiers injured in the wars in Iraq and Afghanistan (2003-11 and 2001-present) was cited by some as the main impetus for the Government’s drive to improve civilian trauma care after another NAO report focusing on civilian trauma care, and released the same week, raised a number of serious concerns.\textsuperscript{17,7} Military and civilian trauma care is, and should be, inextricably linked and it is essential that both parties continue to work together to translate lessons learnt in one forum to benefit the other.

A key facet in surviving traumatic injury, whether military or civilian, depends upon reaching definitive care as soon as possible after the injury, captured in the mantra ‘the right patient in the right place at the right time.’\textsuperscript{18} The world’s first dedicated civilian trauma hospital was established in 1941 with the opening of the Birmingham Accident Hospital in the United Kingdom. Here, teams of specialist clinicians working alongside physiotherapists and occupational therapists cared for the victims of mainly industrial and road accidents. In 1961, the first trauma unit was opened in the USA at the University of Maryland, followed, in 1966 by trauma centres being established at Cook County Hospital, Chicago and San Francisco General Hospital. In the same year, a landmark report ‘Accidental death and disability – the neglected disease of modern society’ was published by the U.S. National Academy of Science.\textsuperscript{19} In this report, the investigators examined the quality and availability of trauma care in the USA and recommended urgent changes to the structure and funding of such care, along with a need for improved data collection, education and research. This was subsequently followed by legislative change, such as the National Highway Safety Act of 1966 and the expansion of trauma centres across the U.S. In order to promote optimal trauma care, the American College of Surgeons (ACS) published criteria for the verification of trauma centres.\textsuperscript{20}
In the USA, official designation is determined by individual state law, and trauma centres vary in their capabilities and are identified by ‘level’ designation: Level I being a Major Trauma Centre and providing a comprehensive trauma service to level V which offers limited trauma care (Box 1). However, as verification is a voluntary process, many US hospitals not verified by the American College of Surgeons claim trauma centre designation.

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<td>Level I</td>
<td>Provides comprehensive trauma care, serves as a regional resource and provides leadership in education, research and system planning.</td>
<td>A level I centre is required to have immediate availability of trauma surgeons, anaesthetists, physician specialists, nurses and resuscitation equipment. ACS volume criteria further stipulate that level I centres treat 1200 admissions a year or 240 major trauma patients per year.</td>
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<tr>
<td>Level II</td>
<td>Provides comprehensive trauma care either as a supplement to a level I trauma centre in a large urban area or as the lead hospital in a less population-dense area. Level II centres must meet essentially the same criteria as level I but volume performance standards are not required and may depend on the geographic area served. Centres are not expected to provide leadership in research and teaching.</td>
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<tr>
<td>Level III</td>
<td>Provides prompt assessment, resuscitation, emergency surgery and stabilisation with transfer to a level I or II centre as indicated. Level III facilities typically serve communities that do not have immediate access to a level I or II centre.</td>
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<td>Level IV/V</td>
<td>Provides advanced trauma life support prior to patient transfer in remote areas in which no higher level of care is available. The key role of the level IV centre is to resuscitate and stabilise patients and arrange for their transfer to the closest, most appropriate trauma centre. Level V trauma centres are not formally recognised by the ACS but they are used by some states to further categorise hospitals providing life support prior to transfer.</td>
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Box 1: American College of Surgeons classification system of trauma centre level

It is important to recognise, however, that a trauma centre does not constitute a system. A trauma system is defined by the American College of Surgeons as “An organised, coordinated network of health care resources that provides a broad spectrum of services and definitive medical and surgical care to the acutely injured trauma patient.”
Trauma systems can be further sub-divided into those that are “inclusive” or exclusive. An inclusive trauma system involves regional hospitals and pre-hospital care providers using triage and bypass protocols to deliver the patient to the most appropriate facility. A MTC will play a central role in this network but regional trauma management protocols, injury prevention, education, audit and research all foster a collaborative approach between multiple partners. Fundamental to this approach is the existence of two-way inter-hospital transfer agreements that allow major trauma patients to be directly taken to the trauma centre and repatriated to their ‘local’ hospital when appropriate or if they were ‘over-triaged’ initially. This is the approach that many English regions are taking in their reorganisation of trauma services.

In comparison, an exclusive trauma system focuses solely on the creation and designation of one hospital in a health economy being a stand-alone MTC that may house all surgical specialties and care for the most severely injured within a population. However, it may have no formal links with surrounding hospitals or pre-hospital care providers. This was the approach taken by many American trauma centres, although most are now adopting a more inclusive strategy.

**Trauma system components**

Following an injury, most patients in England and Wales will follow the pathway outlined in Figure 2. An inclusive trauma system will target each one of these elements and implement strategies to attempt to reduce injury in the first place right through to ensuring that those that are injured receive optimal rehabilitation from the outset, providing them with the best chance of survival and, ultimately, returning to work or education.
Figure 2: The trauma patient pathway

There are many elements and processes that make up a trauma system. Over 1500 process measures have been proposed as performance indicators including time to CT scan and the seniority of the trauma team leader.\(^{21}\) Determining which of these factors is important in improving outcome and ensuring a trauma system ‘works’ can be logistically difficult and many are supported by limited research. I will now explore each facet of the patient’s journey through the system separately.

**Injury prevention**

Injury prevention should be seen as an essential component of an inclusive trauma system. It has been estimated that around half of major trauma patients do not survive to reach hospital alive, and these deaths can only be avoided by preventing the injury from occurring in the first place.\(^{22}\) Education, engineering and enforcement are fundamental to successful injury prevention strategies and collecting data through national trauma databases such as TARN can be helpful in identifying areas of potential concern. Such data can then be used to drive change to legislation and help inform strategies to change behaviour.

The state of Victoria in Australia has seen primary prevention strategies such as seat-belt legislation, compulsory wearing of cycle helmets, speed cameras and mandatory blood alcohol tests for all hospitalised trauma patients being credited with substantially reducing the road death toll within the state. Following implementation of such strategies, the trauma fatality rate decreased from 30.8 to 8.4 per 100,000 population between 1970 and 1994.\(^{23}\)
Pre-hospital phase

- Mode of transport
  Despite the perceived increased speed of transporting trauma patients by helicopter compared to land ambulance, their role remains controversial and the evidence is mixed. A number of studies from the US have reported improved outcomes, however, a study evaluating outcome and cost-effectiveness of the London Helicopter Emergency Service found no benefit. Factors such as the geography of the region being covered and skills of the pre-hospital care provider would also likely influence the potential role of helicopter transport and, as such, the results from one study may not extrapolate to all.

- Triage and trauma protocols
  The purpose of triage protocols is to ensure that the right person is taken to the right place at the right time to receive definitive trauma care. For example, it would seem logical to transport a patient with a serious head injury to a hospital that has neuro-surgical services. A number of studies have found that the positive predictive value of pre-hospital triage systems was between 19-25%. Consequently, around 80% of patients were unlikely to benefit from the higher level of trauma provision offered at a major trauma centre. As triage tools are implemented by ambulance services across the country, evaluation will aim to improve the differentiation of those who truly require major trauma centre input.

- Role of pre-hospital care providers
  There is evidence that spending long periods of time with trauma patients at scene by paramedics can have a detrimental effect on outcome. Time is a critical factor. A five-year study from Quebec found that pre-hospital time was independently significantly associated with an increased risk of dying by 5% for every extra minute spent at scene. Consequently, the idea of ‘scoop and run’ rather than ‘stay and play’ may be more suitable for many severely injured patients.
Hospital phase

- Accreditation
  As documented in Box 1, in 1976 the American College of Surgeons committee on trauma published a series of criteria that had to be met if hospitals were to be designated trauma centres. Such centres were given accreditation from level I, providing the highest level of trauma care to level IV, providing the most basic.\textsuperscript{20} Patients treated at level I centres have been shown to have improved survival and functional outcome compared to those treated at a level II centre and even the accreditation process to become a level I centre in itself has been found to have a positive effect on patient outcome.\textsuperscript{26,30,31}

- Trauma team
  The use of trauma teams has been shown to improve outcome, as has the use of resident trauma surgeons and the effect of emergency medicine and trauma surgeons working together on the trauma team.\textsuperscript{32,33,34} The presence of a physician coordinating the overall care of the patient without being focused on one organ system (e.g. orthopaedics) has been shown to benefit the quality of health care delivered.\textsuperscript{35}

- Seniority and leadership
  Trauma resuscitation inevitably involves multiple medical and allied staff working under extreme pressure trying sometimes to solve a multitude of problems. Consequently, good leadership of the situation is pivotal to allow priorities to be ascertained and treated and individuals within a team to be given focused roles. The lack of senior input in the initial stages of caring for trauma patients has been criticised in the UK and has been linked to causing preventable deaths.\textsuperscript{36} Others have demonstrated that survival after major injury is positively related to increased experience and greatest when consultants are present early on in the resuscitation.\textsuperscript{37}
• Training
Courses such as the Advanced Trauma Life Support course provides individuals with a structured approach to managing the severely injured patient.\textsuperscript{38} In one study 97\% of respondents who had taken the course felt that their clinical practice had been improved.\textsuperscript{39} Levels of core knowledge also improve after taking the course.\textsuperscript{40} However, the course has been criticised for not giving enough attention to working in a team and testing communication skills. Consequently, other courses such as the European Trauma Course have been implemented to cover such perceived deficiencies.

• Imaging
The role of X-rays and ultrasound in imaging the patient with major trauma has been questioned as they can miss certain pathology.\textsuperscript{41} With the development of new CT scanners that can scan the whole body in a matter of minutes, whole body CT scanning has been shown to be a predictor of survival in seriously injured patients, compared to no scan or a focused scan.\textsuperscript{42} Consequently, the UK Royal College of Radiologists recommend the use of this modality in severely injured patients\textsuperscript{43} although recent research has shown wide variation in its use within trauma receiving hospitals in the UK, particularly between MTCs and TUs.\textsuperscript{44}

• Time to surgery
For those patients that are acutely bleeding from their injuries, the definitive management will involve transfer to the operating theatre for exploration of wounds and haemostasis of bleeding vessels. In one study of patients bleeding from intra-abdominal trauma, the probability of death increased by around 1\% for every three minutes spent in the Emergency Department.\textsuperscript{45}

In patients with head injuries and sub-dural haematoma (bleeding on the brain), time has also been shown to have a critical effect on outcome with those evacuated within four hours having mortality rates as low as 30\% and functional survival rates as high as 65\%.\textsuperscript{46}
• **Relationship of outcome to volume**

Evidence supporting the need for a volume threshold is limited. Several studies have shown a lower risk of death in centres where large numbers of trauma patients were treated, whereas others based in low-volume centres have not found such a trend. Even though increased volume would suggest increased experience in dealing with seriously injured patients, Demetriades found that while designated major trauma centres had better outcomes than non-designated centres for equivalent patients, volume did not lead to improved outcomes between high and low volume level I centres or between high and low volume level II centres.7

• **Governance**

The implementation of a full-time trauma admitting service at a level I trauma centre in Australia was associated with an 8% reduction in the death rate of the most severely injured. This involved strategies such as the appointment of a full-time trauma medical director, admission of all trauma patients to the trauma service, creation of a trauma quality assurance programme and implementation of trauma practice guidelines.48

Once a trauma system is established, audit of performance, both outcomes and processes, is essential to identify the effect the system is having and whether local and national performance indicators and targets are being met.

**Rehabilitation**

Early access to rehabilitation care following serious injury has been viewed as an essential element of regional trauma systems by NHS England. In fact, hospital trusts are financially incentivised to provide such care. As mentioned above, even though many trauma studies use survival as the sole outcome, the main priority must be to return function to this mainly young population to allow them to return to work or education and social activities. Such service improvements allowing people to get back to work have been shown to repay 5-15 times the healthcare investment.49
Finally, and perhaps most importantly, both nationally and locally there needs to be engagement of involved parties and to foster an interest in trauma care. For local systems to become established and work, there also needs to be ‘buy-in’ from commissioners, managers, physicians and patients.

One particular concern regarding trauma systems has been the cost of providing such care. In the USA, 30% of trauma centres closed between 1999 and 2005 as it has not been seen to be financially viable to provide expensive trauma interventions and care, sometimes including prolonged rehabilitation, to a population that is mainly un-insured. Some regions in the US, such as Nebraska, have developed novel ways to continue to provide trauma care. Here, two hospitals function as a single trauma centre, alternating trauma admissions throughout the week and sharing not only the cost of providing trauma care but also injury prevention and educational programmes.

In England, this issue has been addressed by changing the NHS payment structure for hospitals who deliver trauma care. Additional funding of £37 million was secured as a best practice tariff. Consequently, hospitals receive payment based on meeting quality indicators, such as submission of data to TARN and completion of a patient rehabilitation prescription, with the aim of driving performance improvement through financial incentivisation.

**Trauma system effectiveness**

Several lines of evidence suggest that regional trauma systems are effective in reducing injury related mortality. Most of these studies were observational in nature and were undertaken in the USA and Australia. Two systematic reviews regarding trauma system effectiveness have been carried out, the meta-analysis of one showing a 15% reduction in mortality in favour of the presence of a trauma system. Both only included research from North America and were significantly flawed in their execution. The sole study to be carried out in the UK showed no survival benefit in implementing a trauma service but was criticised on the basis of
methodological flaws, mainly that there was little involvement with local pre-hospital care providers to allow the direct transfer of injured patients straight to the MTC, bypassing local hospitals. Consequently, it functioned solely as an exclusive system.\textsuperscript{57}

Organised trauma systems have also been shown to reduce mortality from individual injuries. In a comparison of mortality in head injured patients treated in a trauma system in Australia against those treated in an area with no developed trauma system in the UK, the odds of death were significantly higher.\textsuperscript{58} Such benefits have also been found in patients sustaining major renal trauma. Those treated in the most inclusive systems had a 30\% lower risk of nephrectomy and were independently associated with a lower case fatality risk compared to those treated in exclusive trauma systems.\textsuperscript{59}

Those patients treated within an inclusive system who initially presented to a non-tertiary hospital and were then transferred to level I trauma centres had lower in-hospital mortality than those remaining at the non-tertiary hospital (after correcting for injury severity). However, there was no measurable benefit found in those transferred to level II trauma centres.\textsuperscript{60} This finding has subsequently been supported by others.\textsuperscript{61} However, signs of improvement may also not be instantaneous. In a nationwide US study assessing the effect of regionalisation on mortality from motor vehicle collisions, an 8\% reduction in the risk of death took eight years to manifest. Similarly, in Oregon, a measurable reduction in trauma mortality was not demonstrated for several years post trauma system implementation.\textsuperscript{62}

Most evaluations of trauma outcomes are based on whether the patient is alive or dead at the end of their hospital admission. However, although mortality is affected by many variables it is overwhelmingly a consequence of the injuries sustained. Therefore, the effect of interventions on mortality may be small in massively injured patients. Conversely, some injuries, such as hand injuries, may be associated with significant loss of function but carry little mortality.\textsuperscript{63} Collecting outcomes other than death can be difficult and time consuming. Long-term patient focused outcomes such as level of function and quality of life have not been validated for trauma
care. The patient population is also mobile and often unwilling to access healthcare services making long term follow-up difficult.

As patients with minor injuries almost always survive, mortality is a poor outcome measure when evaluating trauma care. In a large study of over 470,000 patients, among minimally, moderately and severely injured blunt trauma patients those receiving care at a higher tiered trauma centre (level I/II) had a higher likelihood of total independence, as measured by the modified Functional Independence Measure compared to a lower tiered trauma facility (level III, IV). Improved functional outcome has also been shown in those who sustain traumatic brain injury and are treated in level I compared to level II trauma centres. However, this was significantly associated with functional independence and independent expression after severe, but not moderate injury. Other injury groups that have also been shown to gain a functional benefit from level I trauma centres include those with major high-energy lower limb trauma, measured using the Medical Outcomes Study Short Form Health Survey (SF-36) and the Musculoskeletal Function Assessment.

Two particularly important groups of trauma patients are children and older people. They have different physiology and physiological reserve, may present with different injury patterns to young adults and may have different care needs, including rehabilitation. Trauma is the leading cause of death in children aged one to 15 years. Whilst adult trauma centres and systems have become widely implemented across the United States this cannot be said for paediatric trauma facilities. In fact, a higher proportion of such cases are seen at adult trauma centres or adult trauma centres that have added paediatric skills. Stand-alone paediatric trauma centres are rare.

Consequently, the role and impact of the adult trauma centre in the treatment of children is substantial, both in the USA and in the UK. Whilst some English regions have stand-alone children’s hospitals that manage trauma, most rely on mixed hospitals (both adults and children) to provide this service. Following the implementation of regional trauma systems in England, this situation has remained the case.
Some argue that there is no difference in outcome between children treated at paediatric trauma centres or adult (mixed) trauma centres as these centres represent the highest level of trauma care for the seriously injured. A review of more than sixty published articles on paediatric trauma outcomes concluded that enough data did not exist to determine conclusively which type of trauma centre was better in the delivery of paediatric care. Most of the studies included were descriptive, single institutional or contained unadjusted analysis.

However, more recently, a large US database study of 53,700 children seen at level I trauma centres showed improved overall survival was associated with patients treated at adult trauma centres that housed added paediatric skills. Children aged three to 12 years, those with injury scores >25 and those with Glasgow Coma Scores <8 all demonstrated significant reductions in the odds of death compared to those treated at adult trauma centres without paediatric skills.

The injured elderly population is also a distinct sub-set from their younger counterparts differing in physiological reserve, wound healing and the injury mechanism itself. They have been shown to receive sub-standard care compared to younger patients with examples including delays to transfer to trauma centres from non-trauma centres and less aggressive surgical intervention. Trauma centres that have low risk-adjusted mortality for young adults do not necessarily do so for elderly patients.

However, aggressive treatment in patients over 75 years has been shown to result in the majority of patients returning home and 85% retaining functional independence. The role of geriatricians being involved in the care of this population along with trauma teams has also been favourably reported, especially in reducing hospital acquired complications. The average of major trauma patients is increasing and within the next few years, it is believed that the elderly will be the single largest group suffering major trauma in the UK. Consequently, trauma systems must adapt to meet their needs.
Conclusion

In this chapter I have sought to describe the processes of care for those seriously injured in the UK both before and after reorganisation of care. I have introduced the concept of a trauma system and presented some of the elements that are key to its structure. I have also touched on some of the controversies regarding the implementation and management of a trauma system, and I will explore these further in the following chapters.

In the next chapter, I will describe a systematic review into the effect of implementing inclusive trauma systems on patient outcomes. Whilst England has introduced large-scale reorganisation of trauma care, I will identify and analyse the evidence, if any, that such a change is based on. From initial reading, it certainly seems that there is a substantial body of knowledge supporting the hypothesis that organised trauma care is beneficial in improving outcomes. Of concern however, is the variable use of trauma system and trauma centre often without clear definition in descriptive papers and papers that concentrate of effectiveness.

However, the importance of individual care processes and system components in improving outcomes within these systems has yet to be elucidated. Such information will be pertinent for the development and implementation of trauma systems throughout the world. I will seek to ascertain, through qualitative and quantitative studies, the components that are deemed fundamental to ensuring that a trauma system functions effectively and what it is about a system that makes it ‘work’.

Qualitative research seems to have been under-utilised in examining the impact of trauma systems. Through interviewing those involved in such systems I will look to explore whether they felt change to trauma care was needed, how change was implemented and whether they feel that patient care and outcomes have improved. I will then carry out a quantitative analysis, using data from the national trauma database, presenting patient outcomes and process measures before, during and after the implementation of trauma systems in two regions of England, using Wales, a country that is yet to introduce such a system, as a control.
I hope that this work will then add to the body of evidence surrounding trauma systems so that we can be better placed in designing and managing efficient structures to manage those seriously injured both here in the UK and around the world.
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Chapter 2:
The effectiveness of inclusive trauma systems on patient outcome
**Background**

In the previous chapter, I outlined the fact that traumatic injury is a major public health problem both in the United Kingdom and around the world. I described some of the interventions that have been introduced by governments and health services to try to reduce the number of those killed and seriously injured and also to improve the likelihood of good functional outcome in patients. One such intervention that has been adopted by the NHS in England is the introduction of regional trauma systems. To reiterate, a trauma system serves a defined population to reduce death and disability following injury. The trauma system should ensure that a trauma patient is treated in the right place at the right time by the right people. It may be ‘exclusive’ with the designation of a single hospital as a stand-alone ‘trauma centre’ that functions independently in a health economy, houses all surgical specialties and where all severely injured patients within a region are taken, or the trauma system can be ‘inclusive’.

An inclusive system requires optimisation of pre-hospital triage, bypass protocols, development of trauma unit emergency management protocols and rapid inter-hospital major trauma centre transfer capability. The system includes public health, injury prevention, emergency medical services, all trauma receiving hospitals, major trauma centres, rehabilitation services, research, education and systems governance. Inclusive trauma systems were implemented in London in 2010 and throughout the rest of England since 2012.

Such systems have been functioning in parts of the United States and Australia for many years and many research papers highlight their benefits.\textsuperscript{1,2} Indeed, many of the documents produced by the NHS and other UK bodies quoted such evidence in their call for improvements to trauma care and in their guidance to NHS regions on how to implement such systems.\textsuperscript{3,4,5}

**Why it is important to carry out this review**

Trauma systems in England have undergone widespread re-configuration and continue to be modified. Other regions of the UK such as Wales and Northern Ireland are actively exploring introducing similar systems, as are other countries throughout the world, particularly low and middle-income countries, for whom the burden of trauma is greatest.\textsuperscript{6,7} Whilst trauma extolls a
large health and economic burden on countries, the implementation of trauma systems involves the large scale re-organisation of multiple health care providers and are potentially very costly to implement, both in the time taken to do so and the financial resources required. Consequently, such huge change within health systems should be informed by the best available research evidence. One such way of identifying, evaluating and summarising the findings of all relevant individual studies is to carry out a systematic review. This review will also aim to provide reliable estimates of intervention effects and highlight areas for further research.

To justify whether a new systematic review was required, a literature search was performed in February 2013, to identify existing, ongoing, or planned reviews. The Cochrane Database of Systematic Reviews and Database of Abstracts of Reviews of Effects (DARE) were searched using the search terms ‘trauma system’, ‘trauma care’, ‘trauma service’ and ‘trauma centre’. The National Institute of Health and Clinical Excellence (NICE), NIHR Health Technology Assessment Programme, Scottish Intercollegiate Guidelines Network, and the National Guidelines Clearinghouse were additionally searched. Finally, MEDLINE was searched using the above search terms with the additional controlled vocabulary terms ‘specialist care’, ‘meta-analysis’ and ‘review’.

A title was registered in February 2010 by Mwandri et al with the Cochrane Effective Practice and Organisation of Care Group (EPoC) entitled ‘Organized trauma systems and designated trauma centers for improving outcomes in injured patients’, however this had not been completed by the time of my review. Two systematic reviews were published in 1999 and 2006 but examined the effect of implementation of different levels of trauma system from the most exclusive (e.g. a single local trauma centre) to the most inclusive (e.g. regionalised trauma care). Both reviews were also limited by confining studies to North America. No other relevant systematic reviews were identified. In the absence of a recent, valid review, a new systematic review examining the effectiveness of the implementation of inclusive trauma systems was therefore indicated.
Objectives

The systematic review question is:

"In adults who have sustained a serious injury, does treatment within a 'inclusive' trauma system result in reduced mortality and disability, compared to receiving treatment in an 'exclusive' trauma system or 'standard care'."

Objective 1: Randomised controlled trials (RCT) are the gold standard study design for assessing interventions. In the event of valid RCT evidence, I aim to determine a pooled estimate for the effect of treatment within an inclusive trauma system on mortality, morbidity and adverse events in severely injured adult patients.

Objective 2: In the absence of rigorous RCT evidence I will perform a best evidence review providing an explicit evaluation of the strengths and weaknesses of available non-randomised studies to inform healthcare and research planning.
Criteria for considering studies for this review

Types of studies
All published and unpublished randomised controlled studies comparing the outcome of seriously injured patients after the implementation of an inclusive trauma system compared to previous standard care. In the absence of randomised studies, observational evidence such as non-randomised studies, cohort studies, controlled before and after studies and before and after comparison studies will be included. Population based studies are preferable but registry studies will also be included.

Types of participants
Studies investigating patients presenting with serious injury (ISS ≥15) and treated within an inclusive trauma system are eligible. Studies specifically looking at patients with particular anatomical injury, for example, head or splenic injury, are excluded as are those that exclude deaths in the Emergency Department. Studies that solely focus on the paediatric population are also excluded.

Types of interventions
The unexposed group comprised patients provided with standard care, either before an inclusive trauma system was implemented, were located in an area without such facilities or had been randomly assigned such care. The exposed group were treated within a trauma system that met the NHS definition of an inclusive system:

“A inclusive trauma system describes a model in which commissioners; providers, public health representatives and other stakeholders of trauma care in a geographical region collaborate to plan, provide and manage the treatment of people injured as a result of major trauma. It also features:

- hospital 'bypass’ protocols to allow the patient to be treated initially in the most appropriate place
- a population-based approach to the assessment of need and the provision of treatment
- a role for every hospital and provider of care
• provision for the speedy transfer of patients between facilities
• a quality assurance structure that penetrates across the region”

Studies examining the implementation of ‘exclusive’ systems or single trauma centres, the change in trauma centre verification, examining differences between different level of trauma centre or the effect of single process changes (e.g. transportation), were excluded.

**Types of outcome measures**

**Primary**
- Mortality (from hospital admission to two years post injury)
- Disability e.g. patient reported outcomes such as EQ5D for quality of life and Glasgow Outcome Score Extended (GOSE) for long-term outcomes, from discharge from hospital to two years post injury

**Secondary**
- Frequency of complications such as pneumonia and multi-organ failure whilst admitted to hospital
- Length of hospital and ICU stay
- Cost of providing trauma care

**Search methods for identification of studies**

I searched the following electronic databases:

• Cochrane Injuries Group Specialised Register
• Cochrane Central Register of Controlled Trials (CENTRAL)
• MEDLINE (from 1946)
• EMBASE (from 1974)
• Cumulative Index to Nursing and Allied Health Literature (CINAHL) (from 1980)
• Clinicaltrials.gov
• Evidence.nhs.uk
I conducted a grey literature search to identify studies not included in the databases listed above (www.opengrey.eu), checked reference lists of all retrieved articles and existing literature reviews and, where possible, contacted experts in the field and the relevant study authors to identify further potentially eligible studies that may not yet have been published.

Search strategies for bibliographic databases were developed in conjunction with an information services specialist and underwent expert peer review by the University of Manchester systematic review service. References were managed using EndNote software (Thomson Reuters, CA, USA).

The searches were not restricted by publication status, date, language nor country of publication.

The full search strategies used to search MEDLINE and EMBASE are presented in Appendix 1. The searches of the other databases were based on these strategies. A current awareness search was conducted prior to completion of the systematic review to identify any recently published research.

In January 2018, prior to submitting this thesis, I undertook an updated evidence search to ensure that any relevant research published in the intervening five years could be identified, reviewed and added to the synthesis, if eligible. The updated search utilised identical search criteria to those presented above. The results of this updated review are presented prior to the discussion of the results and are integrated into the quality of evidence summary.
Methods of the review

Registration and protocol
A detailed review protocol stating a pre-specified analysis plan was developed prior to data collection and registered with PROSPERO (CRD42013004595). Any changes to the registered protocol were recorded and post hoc deviations clearly stated.

Selection of studies
Following the retrieval of all titles and abstracts identified through electronic searching, these were downloaded onto a reference management database where duplicates were removed. Two reviewers (MD and SR) then independently examined titles and abstracts for eligibility. We retrieved the full text of all relevant publications and the two reviewers then independently assessed whether each met the pre-defined inclusion criteria. Disagreement was initially approached through discussion between reviewers with adjudication by a third reviewer (FL) where agreement could not be reached. The flow of information through the different stages of the review will be documented in a PRISMA flow diagram, whilst studies excluded following review of the full text publication will be outlined in a 'Characteristics of excluded studies' table.

Data extraction
Data were then extracted independently from included studies by the two reviewers. The following information was collated onto a standardised, data extraction form, documenting:

- Study characteristics (Methods)
- Participants
- Interventions
- Outcomes
- Eligibility of study
Assessment of methodological quality

The risk of bias for each study was independently assessed by two un-blinded reviewers (MD and SR) who explicitly recorded the aspects of study design on which judgments were based. Disagreements between reviewers were resolved by consensus using the third party (FL) as an adjudicator, if necessary. Inter-reviewer reliability was assessed using the kappa statistic.

It was planned that randomised studies would be assessed using the Cochrane ‘Risk of bias’ tool.14 This assesses seven domains: sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessors, incomplete outcome data, selective reporting, and other sources of bias. The risk of bias would be classed as ‘high’, ‘low’ or ‘unclear’.

The risk of bias for each included non-randomised study was assessed using the modified 27 point Downs and Black scoring system.15 The checklist contains five subcategories, including reporting quality, external validity, internal validity, confounding and statistical power. In the modified score, one point is awarded where the results of a sample size or power calculation is reported, rather than rating up to five points for a range of study powers.16 Consequently, the maximum possible score was 28. Studies were rated as excellent (24-28 points) good (19-23 points), fair (14-18 points) and poor (<14 points).17 No studies were excluded solely due to bias.

Measures of treatment effect

The effect of any intervention was estimated using Risk Ratio’s or Odds Ratio’s for dichotomous outcomes, depending on the data presented in the studies and their 95% Confidence Intervals. Weighted or standardised mean difference were used for continuous outcomes.
Data analysis

A meta-analysis was planned to be performed on aggregate data if studies were clinically homogeneous and judged to be of high methodological quality with low risk of bias. Such data would then be pooled using RevMan software (version 5.1, Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2012). If study heterogeneity in terms of populations, study design, interventions or outcomes was too great and a quantitative synthesis was not possible, a narrative synthesis of the evidence would be undertaken. This would be based on a framework developed by the UK Centre for Reviews and Dissemination (CRD) and would describe any trends in outcome following the implementation of inclusive trauma systems in populations throughout the world.18

Strength of body of evidence

The two reviewers (MD and SR) independently assessed the quality of the evidence and strength of their recommendations relating to each outcome according to the expert consensus of the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) working group.19 The quality of evidence was initially determined by study design to be either very low, low, moderate or high, although could be upgraded or downgraded depending on the certainty of the evidence. The results are presented in a ‘Summary of findings’ table format.

Description of Studies

The search of electronic databases identified a total of 2412 citations. An additional 98 citations were identified from other sources including the consultation of reference lists and correspondence with subject experts. A total of 1273 publications were consequently screened for eligibility following removal of duplicates.

Of these, 1135 publications were excluded for clearly having no reference to the inclusion criteria on the basis of the report title (e.g. research on psychological trauma rather than trauma systems). The full text articles were retrieved for the remaining 138 citations and 113 were
excluded after reviewing the abstract as they did not address the review question. Following detailed evaluation of the remaining 28 articles, a further 21 were excluded as they contained ineligible populations or did not meet inclusion criteria. The mean Downs-Black score of these excluded studies was 18 (‘fair’). No articles were excluded due to the unavailability of the full text.

Ultimately, four articles were identified for inclusion in the review. All were published in peer-reviewed publications. No RCTs were identified and studies selected for inclusion were observational studies, reported in English and conducted in Australia, North America and the Netherlands. Their characteristics are outlined in Appendix 2. The mean Downs-Black score of these included studies was 23 (‘good’). The study selection process is summarised in Figure 3.
Figure 3: PRISMA flowchart describing systematic review study selection
Research papers included in quantitative synthesis from 1950-February 2013

Cameron, 2008²⁰

This population based cohort study was undertaken in the state of Victoria, Australia using data from the Victoria State Trauma Registry (VSTR). The objective was to determine whether the implementation of a state-wide inclusive trauma system resulted in improved survival for those seriously injured in the state. The main outcome measure was in-hospital mortality.

The regional system was implemented in stages from 2000 and was fully operational in 2003. Twenty-one hospitals within the state were designated as level I or II Major Trauma Services (MTS) with the remaining 117 hospitals also assigned roles within the system. Triage guidelines were implemented to direct all severely injured patients to a MTS if one was available within 30 minutes transport. All non-MTS hospitals were instructed to transfer patients to an MTS if they fulfilled major trauma criteria.

The study included major trauma patients with an Injury Severity Score (ISS) ≥15 (severely injured) captured by the VSTR between July 2001 and June 2006. Inclusion criteria to the VSTS include:

- Death due to injury
- An ISS ≥ 15
- Injury requiring urgent surgery
- Hospital stay of over 24 hours requiring mechanical ventilation

The study compared inpatient mortality through the period of implementation of a regional trauma system. The unadjusted inpatient death rate fell over the study period from 15% in 2001-2 to 11% in 2005-6. Adjusting for key predictors of mortality, there was a significant overall reduction between 2001/2 and 2005/6 in the risk of death for patients treated in the trauma system (adjusted odds ratio (AOR) 0.62 [95% CI 0.48-0.8]). Significant reductions in the odds of inpatient mortality were also apparent in patients who had suffered motor vehicle collisions.
Median length of stay (LOS) in hospital declined from nine days (IQR, 4.5-17.6) to 8.3 (IQR, 4.3-15.8) over the five year period. LOS on Intensive Care Unit (ICU) also decreased from five days in 2001/2 (IQR, 2-11) to four days (IQR, 2-10) in 2005/6. Cost, complications and quality of life indices were not examined in this study.

In this population based cohort study, the outcome of patients with major trauma treated within state of Victoria hospitals was compared during the staged implementation of an inclusive trauma system. The paper does not qualify how far advanced the system was when the study commenced in 2001 but it is known that the state was home to a level I trauma centre, even if triage, bypass and transfer protocols had not yet been implemented. Consequently, it is a longitudinal study of outcome as the system evolves, rather than a before and after study. There is also no control region to allow for the effect in temporal trends that may have had an impact on trauma care during this period (e.g. implementation of national head injury guidelines).

Data for analysis was obtained from the Victoria State Trauma registry. This was implemented in 2001 at the start of the study period. There is no reference to data quality or to whether all hospitals submit data to the registry. One would expect that the number and quality of submissions would improve over time. Incomplete enrolment of cases could result in selection bias. Despite adjusting mortality rates for well-established predictors of mortality in major trauma such as ISS, physiological derangement and age, there was no adjustment for co-morbid conditions. This could lead to confounding.

The outcome measures in this study were inpatient mortality and hospital and ICU LOS. As this information is objective and obtained from routine administrative data by trained data collectors, it is at low risk of information bias.
Despite the system being inclusive with a state-wide trauma registry with linkage between hospital, pre-hospital and community health care providers, no data is provided on out-of-hospital trauma deaths. A truly inclusive trauma system should play a role in injury prevention strategies and by not taking account of pre-hospital deaths, the study is not truly representative at a population level. Even though inpatient mortality and LOS are used as measures of effectiveness in this study, other factors, such as quality of life scores, may be more pertinent to patients and represent the effectiveness of the system in improving patient outcome rather than solely keeping people alive.

Mullins, 1997

This controlled before and after study was undertaken in the state of Oregon, USA. Its neighbour, Washington state, was used to control for temporal trends following the introduction of an inclusive system in 1990. The objective of the study was to evaluate whether the introduction of such a system throughout the state reduced the risk of death for trauma patients.

The Oregon trauma system was implemented from 1986 to 1990 when trauma centres were designated (level I-IV). Emphasis was also placed on encouraging higher level trauma centres to support those less advanced and on trauma triage, bypass and inter-hospital transfer protocols within the state to ensure that seriously injured patients reach a facility where definitive care could be offered quickly.

The study compared inpatient mortality in Oregon state prior to the implementation of the system (1985-1988) and when both it and Washington state had similar systems of trauma care, to a period following the implementation of the inclusive system (1990-93). During this period, Washington state had not further developed its standard system of trauma care, hence it was used as a control region.

Data was obtained from hospital discharge claims, converting International Classification of Disease (ICD)-9 codes into Abbreviated Injury Scores (AIS) then ISS scores using a conversion algorithm.
This before and after study comparing the regional inpatient mortality rate prior to implementing a trauma system with a period following its introduction, found no difference between the risk-adjusted odds of death between the experimental and control states before system implementation.

A significant reduction in the risk of death was noted in the experimental region in patients with an ISS $\geq 15$ compared with the control region (AOR 0.8, [95% CI 0.7-0.91]), following the implementation of the trauma system. Injury sub-group analysis showed that the risk of death was particularly reduced in patients with traumatic brain injuries (AOR 0.7, [95% CI 0.59-0.82]) or liver/spleen injuries (AOR 0.73, [95% CI 0.54-0.99]). No data pertaining to hospital or ICU LOS was given. Cost, quality of life indices and complications were also not examined.

In this study, data was obtained from administrative records rather than clinical notes. ICD-9 codes were then used to produce a AIS and ISS score. Using this methodology has been criticised by some in the trauma community as it is thought to potentially over-estimate injury severity. Physiological data, known to be an important predictor of trauma patient outcome (e.g. Glasgow Coma Scale (GCS)) was also unable to be collected from administrative notes and was subsequently adjusted for, and, depending on the performance of their risk adjustment models, places this study at very high risk of bias.

Those aged over 80 years were excluded from the study, although, in fact, patients aged 80 years and older who died, represented the largest number of hospitalised injured patients who died. In an ageing population, it would seem pertinent to include this growing sub-group. It was also the case that only some ICD-9 coded injuries that the research team felt constituted ‘major trauma’ were included in the study. This approach to defining major trauma has not been validated and it is of note that only around 10% of all trauma patients fell within this category. Such incomplete enrolment of cases could result in selection bias.
During the experimental period, Washington state, the ‘control’, was developing its trauma system, even though it had not been fully established. The state is home to an extremely advanced and mature trauma centre (Harbourview) and the state is known to have a well-established system of inter-hospital transfer. One explanation for only a modest difference in risk-adjusted odds of death between the two states may be that Washington state was not truly representative of a state without a trauma system and therefore underestimates the beneficial effect of Oregon’s ‘new’ trauma system.

Mortality was the primary outcome in this study. This information is objective and is at low risk of information bias, despite un-blinded outcome assessors. However, using mortality rates as the sole marker of system effectiveness is crude and the study could have considered outcomes such as patient’s functional outcome, hospital length of stay and cost as other markers of system performance. However, such data were not available through administrative databases.

Sampalis, 1999

This was a prospective cohort study carried out in the province of Quebec, Canada between April 1st 1993 and March 31st 1998. This coincided with four distinct phases in the development of an inclusive, state-wide trauma system; pre-regionalisation, initiation, intermediate and advanced. The objective of the study was to evaluate the impact of trauma care regionalisation on the mortality of major trauma patients. The main outcome measure was inpatient mortality.

The process of trauma care regionalisation was commenced in 1993 and over the following three years a programme involving the verification of trauma centres, implementing hospital bypass and transfer protocols and developing education and research programmes was undertaken.

The study included all trauma patients who were treated in any acute care hospital in Montreal or Quebec City and met one of the following criteria: ISS ≥12, died in hospital as a result of their injury, had a pre-hospital index >3, had a hospital stay of >3 days or had two or more injuries with an AIS >3. Data were collected from the Quebec Trauma Registry and from reviewing all
medical records from acute care hospitals in both regions.

This prospective study compared inpatient mortality before, during and after the implementation of an inclusive trauma system. 12,208 patients met the study inclusion criteria. During the study period MVCs and falls were responsible for more than 80% of all injuries.

The primary outcome measure was survival to hospital discharge and the proportion of patients who were discharged alive increased from 48% in 1992-3 to 82% in 1997-8. This represented a decrease in the unadjusted mortality rate from 52% to 18% over the same period (p=<0.001). However, the change in mortality for the patients with the highest ISS (>50) was not significant. When analysing the data by phase of regionalisation, the unadjusted mortality rate decreased from 52% before regionalisation, to 32% during the initial phase of regionalisation, to 19% in the intermediate phase and to 18% during the advanced phase.

Adjusting for ISS and patient age, compared with the pre-implementation phase, the adjusted odds of dying were 0.39 (95% CI 0.34-0.45), 0.18 (95% CI 0.16—0.21) and 0.15 (95% CI 0.12-0.18) during the initiation, intermediate and advanced phases, respectively (p=<0.001). Cost, quality of life indices and complication rates were not examined.

In this prospective cohort study, the outcome of seriously injured trauma patients was compared before, during and after the implementation of a province wide inclusive trauma system in Canada. However, this study only evaluated hospitals in Montreal and Quebec City, not the entire province. Consequently, the study may be biased toward patients receiving higher level trauma care within shorter time-frames. By including hospitals outside of these two regions, which may reflect the longer transport times of more rural areas and the effect of bypass and transfer arrangements, it would demonstrate the effect that regionalised care has had on the entire system.

Data were extracted from the database by trained, independent, injury coding staff. As mortality was the primary outcome, its objective nature means that information bias was likely to be low,
though no information was given as to data quality and its completeness. In this study, there was also no control region to allow for temporal trends, the effect of which has been described previously. Despite confounding for age and ISS, residual confounders may exist.

Twijnstra, 2010

This before and after study compared trauma patient outcome of those treated in hospitals in the central region of the Netherlands before the implementation of an inclusive trauma system (1996-98) to patients treated in the same hospitals following the introduction of the system (2003-05). The system was introduced in 1999. The main objective was to quantify whether establishment of an inclusive trauma system reduced in-hospital mortality.

The central region contained one regional trauma centre and 12 regional acute care hospitals, categorised according to the level of trauma care that they provide. There were guidelines for ambulance crews to triage trauma patients to the most appropriate hospitals.

Data were extracted from the Dutch National Medical Registration database that contained information on all hospital admissions, discharge diagnoses, procedures and outcomes in the Netherlands. All diagnoses were coded according to the ICD-9 classification. AIS scores were derived from ICD-9 codes by a validated conversion table and the ISS determined. Adjustment was made for confounding from age, gender, injury severity, body region, comorbidity, intent and mechanism of injury.

This (non-controlled) before and after study included 33,210 patients in the group prior to trauma system implementation and 34,380 in the group treated following implementation. Before implementation of the trauma system (1996-98), 2.6% of injured hospitalised patients died, after the system was established, this fell to 2.3%. The crude odds ratio for in-patient mortality was 0.89 (95% CI 0.8-0.98), however, between the before and after group, there were statistically significant differences in age, comorbidity, ISS, intent, mechanism and body region injured. Following adjustment for confounding the odds ratio was 0.84 (95% CI 0.76-0.94). The risk of death after trauma system implementation decreased especially for patients with mild
injuries (ISS<9) (OR 0.78 [95% CI 0.72-0.82]). However, for patients with more severe injuries, there was no evidence of effect with the adjusted odds ratio of inpatient mortality in patients with an ISS 9-15 of 0.9 (95% CI 0.79-1.02) and ISS >15, 0.79 (95% CI 0.59-1.05). Cost, complications and length of stay were not examined in this study.

The only European study to be included in this review, this before and after study compared inpatient mortality prior to and following the introduction of an inclusive trauma system in a region of the Netherlands. As it was not controlled it is impossible to ensure that the reduction in inpatient death is solely due to the implementation of the trauma system. Between the study periods, advances in other elements of trauma care such as medications, surgical technology and standard clinical practice may have changed and influenced outcome. Despite adjustment for confounding, there may be some residual confounding factors that were not accounted for.

Data were extracted from the Dutch National Medical Registration database. This includes all patients admitted to hospital in the Netherlands and is not specifically a trauma registry. Consequently, physiological data are not collected and thus patient ISS had to be calculated from ICD-9 diagnoses. This technique has been criticised and is not widely used in Europe. Despite the system being implemented throughout the Netherlands and pan-country data being available, only one of ten regions was studied. This region already had a fully functioning major trauma centre (University Hospital Utrecht) prior to the inclusive system being introduced and this may not have been the same in other regions. Consequently, the demonstration of effectiveness of such a system may have been greater if studied throughout the country as a whole.

Mortality was the primary outcome in this study although no information was given as to how data were extracted. However, the study is unlikely to be susceptible to information bias. There was also no reference made to data quality. Once again, using mortality as a sole measure of system effectiveness is crude and by excluding pre-hospital deaths the study does not account of the effectiveness of injury prevention efforts that should be seen as part of an inclusive trauma system.
Excluded studies

We identified a number of relevant observational studies. Each is described in detail in Appendix 3. These studies were deemed ineligible to be included as they did not meet inclusion criteria as they focused on a particular anatomical injury sub-group (e.g. head) or did not use a control group/period with which to examine system effectiveness in comparing outcome. One paper worth particular mention is that of Nicholl et al, being the only one to present research conducted in the UK. This controlled before and after study examined outcomes between 1990 and 1993 following the introduction of a trauma ‘system’ in 1991-2 in the West Midlands region of the UK. With the financial support of the UK Department of Health, North Staffordshire Royal Infirmary became a regional ‘trauma centre’ offering 24-hour consultant presence and increased ICU resources. Five regional district general hospital emergency departments fed into the system supported by three ambulance trusts. Two control regions in Lancashire and Humberside were used to control for temporal effects.

Following standardisation, the authors determined that the estimated change in the probability of dying in the experimental region compared to the control regions was -0.8% per year (95% CI -3.6-2.2), for out-of-hours care the change was 1.6% (95% CI -2.3%-5.6%) and, for multiply injured patients, the change was -1.6% (95% CI -6.1-2.6%). Consequently, the authors felt that large scale introduction of trauma systems throughout England would provide very modest reductions in mortality.

However, the paper was excluded from my review for a number of reasons. Firstly, the system that was developed was not inclusive. All the extra financial resources were focused at the ‘major trauma centre’, there was no formal pre-hospital bypass protocols agreed between the three ambulance trusts and there was little evidence of working together with the other hospitals that fed into it. Also, the study only assessed change for a very short period of time following the introduction of the ‘system’ when some studies suggest that improvements in outcome can take many years to come to fruition as the system matures. Finally, despite the changes showing little benefit in the West Midlands, these findings may not be generalisable to other regions of the UK, particularly more urban areas, where the pattern of trauma may be
Research papers included in qualitative synthesis from February 2013-January 2018

In order to ensure that recently published research was accounted for, an updated evidence search was undertaken based on the exact search criteria of initial systematic review undertaken in 2013. Whilst over 1100 papers were identified since January 1st 2013, 31 were reviewed fully and four met the initial criteria for inclusion. The mean Downs-Black score of these included studies was 23 (‘good’). Two completed systematic reviews of the effectiveness of trauma systems and a protocol for another review were also identified. The search strategies are documented in Appendix 4 and the PRISMA diagram of this updated search is outlined in Appendix 5.

The most recent systematic review published was by Vali et al in 2017 analysing ‘The effectiveness of regionalisation of trauma care services.’ Twenty-four papers met the inclusion criteria including eighteen before and after studies and six studies that employed a more robust design with lower risk of bias. Whilst all but one study found a reduction in mortality following regionalisation, two controlled before and after studies were eligible for meta-analysis and the results showed a significant reduction in mortality following implementation of a organised trauma system (OR 0.84 (95% CI 0.756-0.924). Despite recommending further studies utilising more robust design methods, they concluded that their results supported the reorganisation of trauma care services. The review was limited by many of the studies not sufficiently detailing their organisational structure to determine ‘inclusiveness’ and the included studies being at high risk of bias.

The second systematic review entitled ‘Impact of trauma system structure on injury outcomes: A systematic review and meta-analysis’ was also published in 2017. This review studied the effect of components of trauma systems on their effectiveness, ‘inclusiveness’ being one such component. Five studies evaluating the impact of an inclusive system design were identified, all of low quality study design. However, all five studies reported a reduction in mortality and substantial difference.
meta-analysis found the overall effect to be OR 0.72 (95% CI 0.65, 0.8). The primary limitation of this review is that the methodological quality of the studies included in the meta-analysis was poor as they were observational and failed to take account of confounders. They also did not describe how they defined an ‘inclusive’ system.

The third systematic review identified is at protocol level only and was published in 2017. It is titled ‘Organised trauma systems and designated trauma centres for improving outcome in injured patients.’

Four published research papers were identified that would have met inclusion into the systematic review presented in Chapter two. I will outline each individually:

**Metcalfe et al 2016**

This observational study utilised the TARN database and data from the ONS and examined the effect of hospitals in England becoming MTCs from 270 days before to 270 days after. Outcomes included quality indicators of care such as seniority of doctor attending to the patient and clinical outcomes such as death in hospital. The examined data from all hospitals that had been designated MTCs and submitted data to TARN and took account of the phased implementation that occurred in some regions.

Overall, 20181 cases were included. All reported quality indicators such as consultant input and time to CT scan showed statistically significant improvement following MTC designation. However, crude mortality and standardised risk adjusted excess survival rates (Ws) did not show any improvement over the study period (Pre Ws -0.17 (95% CI -0.68, 0.34) vs 0.03 (95% CI -0.36-0.43) post). Reporting to TARN increased following MTC designation as did median age.

A limitation of the study is that it only examined the effect of trauma system implementation on MTCs and not all hospitals within the system. It also focused on a very short period of time (nine months) before and after implementation when other studies have shown that the true
The effect of such change can take years to come about. The jump in the case ascertainment to TARN after MTC designation is likely due to financial incentivisation through the Best Practice Tariff for hospitals to report, rather than a true large jump in trauma patients.

Cole et al 2015

This prospective cohort study compared the quality of care delivered to patients treated in MTCs and TUs of the Greater London trauma system, as well as outcomes, over a three-month period between February – April 2013, nearly three years on from system implementation. Using the same methodology that was used by investigators from the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) in 2007, all trauma patients with ISS $\geq$15 were identified that were treated in MTCs or TUs in the system. Data collected from patient notes detailing the pre-hospital phase to 72 hours after admission was reviewed by external experts and quality of care graded.

In the 321 cases that were included in the study, overall quality of care was deemed to have improved (69% receiving 'good' care vs 49% (RR 1.3 (1.2-1.4, p<0.001)), process markers such as consultant delivered care improved from 27% to 88% (RR 3.2, 2.8-3.6, p<0.001) and unadjusted mortality fell from 13% to 7% in those treated at MTCs compared to the original NCEPOD investigation (RR 0.53, 0.28-0.99, p=0.06).

The limitations of this study are that all hospitals in the system were not included. Whilst the investigators had difficulty in gaining access to notes from TUs, non-trauma receiving hospitals were not included. Consequently, the study was biased toward MTCs. The investigators were also unable to compare like for like data as some of the hospitals used in the initial study were outside of London and this data could not be separated out. Consequently, they compared care in an organised trauma system in London with a previous study that examined trauma care in multiple hospitals around England, which may have had very different populations.
Claridge et al 2013\textsuperscript{32}

This non-controlled before and after study compared data on injured patients in Northern Ohio, USA for two years before trauma system implementation to two years after. The regional system consisted of one Level I trauma centre, four level II trauma centres (latterly two), seven non-trauma hospitals and emergency pre-hospital care services. A truly inclusive system was developed with regional protocols, cross collaboration and educational events. A trauma database was also established in 2010.

The study comprised 29,890 patients. The OR of survival post trauma system implementation was 0.81 (95% CI 0.7-0.94) for all patients and 0.76 (95% CI 0.62-0.95) for those most seriously injured (ISS \( \geq 24 \)). The authors suggest that 291 patients survived in the two-year period following trauma system implementation when they would not have been expected to beforehand. Whilst the study shows an early improvement in mortality outcome, it is limited by the fact that there is no control region, no information is presented regarding data quality and missing data and also the study does not compare differences in outcome to particular trauma hospital types in the system (e.g. Level I, non-trauma hospitals).

McKee et al 2015\textsuperscript{33}

A population based non-controlled before and after study comparing adoption of an ‘inclusive’ trauma system in the state of Alberta, Canada between 2002-11. Due to the population being spread over vast distances and transport times to one of two Level I trauma centres being prolonged, a decision was made to enhance the role of the multiple Level III trauma centres, to enable more people to be treated closer to home. Whilst very seriously injured patients were transferred to the Level I centres, there was increased collaboration, improved inter-facility transfer agreements between Level I and III hospitals and enhanced infrastructure.

The Alberta trauma registry was used to provide data on the 21,772 cases included in the study over the ten-year period. A 12% reduction in adjusted hazard of mortality and a one day fall in adjusted hospital length of stay was noted after the implementation of the inclusive system.
However, the adjusted hazard of mortality for the sub-group of patients with severe head injury was higher than those treated in a Level I trauma centre (1.25, 1.23-1.18, p<0.001).

Due to the huge distances involved in transporting trauma patients in this environment, this system may be well adapted. However, it will not be generalisable to all populations. As the study took place over a 10-year period there may well have been secular trends, such as general improvements in trauma care, that were not accounted for.

**Discussion**

The initial review identified four observational studies that examined the effectiveness of implementing inclusive trauma systems on patient outcome. All studies demonstrated a significant fall in the odds of death when patients presenting with traumatic injuries were treated within such a system. Each region could be considered to have implemented inclusive systems as they both operated triage, bypass and inter-hospital bypass protocols and hospitals within each region were defined and governed according to a level of trauma care that could be provided.

In considering the implications of this finding it must be acknowledged that these studies do not provide definitive evidence. The studies were at high overall risk of bias compared to a ‘gold-standard’ RCT and given the modest effect magnitude and potential for confounding and bias, represent a very low-quality body of evidence.

In the updated review, a further four research papers were included. Despite these studies also showing an improvement in survival, the methodological quality of the supporting evidence is low and at high risk of bias. Despite adding these studies to the original review, they would not change the underlying message that further high-quality studies should be undertaken, using robust methods to broaden our knowledge base of the effect of inclusive trauma systems on patient outcomes.
The consensus method for assessing quality of evidence in systematic reviews is based on the GRADE approach. This specifies four outcome-specific levels of quality (high, moderate, low, and very low), with RCTs providing high quality, and observational studies initially rated as very low quality evidence. The body of evidence can be downgraded depending on the presence of factors relating to within-study risk of bias, directness of evidence, heterogeneity, precision of effect estimates, and risk of publication bias; or up-graded due to large effect sizes, dose-response gradients, or plausible biases all working to undermine effect estimates. The GRADE quality of evidence for each outcome is summarised in Table 1. The central limitation of this review is the lack of randomised controlled trial evidence at low risk of bias.
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**Inpatient mortality**

8 | Observational | Very serious | No serious inconsistency | No serious indirectness | No serious imprecision | Small | None | None | AOR 0.17 (0.12-0.19) to 0.8 (0.71-0.9) | 4 less / 100 (from 3 less to 4 less) and 20 less /100 (from 9 less to 30 less /100) | Very low |

Length of hospital stay measured with administrative records

3 | Observational | Very serious | No serious inconsistency | No serious indirectness | No serious imprecision | - | None | - | Median LOS fell from 11 (95%CI 3.2-15.6) to 10 (95%CI 3.9-14.8) days | Very low |

Length of ICU stay measured with administrative records

2 | Observational | Very serious | No serious inconsistency | No serious indirectness | No serious imprecision | - | None | - | Median LOS decreased from 5 (95%CI 3-14) to 4 (95%CI 2-11) days | Very low |

Quality of life indices (Glasgow Outcome Scale)

1 | Observational | Very serious | No serious inconsistency | No serious indirectness | No serious imprecision | - | None | - | Proportion having ‘good’ recovery increased from 55.5 to 62.3 (p<0.001) | Very low |

Table 1: Summary of systematic review results categorised by GRADE classification
These papers examine changes in trauma care at a regional population level. I identified many other papers that demonstrated improvements in mortality when trauma patients are provided with ‘high-level’ trauma care such as that given at a level I trauma centre compared to a community hospital, and many papers concentrate on a single site or an individual city. Inclusive trauma systems are much more than that. However, defining quite what a trauma system is seems to be interpreted with great variation.

To some, a trauma system is the verification of a few regional hospitals as trauma centres, whilst to others it is the implementation of a region wide structure of hospitals, pre-hospital care providers and individuals with well-defined triage, bypass and hospital transfer protocols, quality improvement programmes and strict governance. Consequently, identifying papers that meet the inclusion criteria of an ‘inclusive trauma system’ has been challenging. Many papers that did meet the criteria were excluded on the basis that they solely focused on a particular injury type or mechanism rather than the effect of the system on a population as a whole.

The trauma systems being implemented in England are planned to be truly inclusive and so it is important to evaluate the evidence in support, or otherwise, of their creation. The generalisability of the evidence presented here to England is debatable. Oregon, Victoria and Utrecht already had established trauma centres, Oregon is likely to have a higher proportion of penetrating trauma and the distances between hospitals are likely to be much greater in those vast areas. The NHS is also free at the point of entry. Even though two papers were included in the updated review based on studies of NHS hospitals pre and post trauma system implementation they are flawed by their very short study periods and by the fact that they only examine outcomes at MTCs (or MTCs and TUs) rather than the population as a whole.

Despite mortality being widely used as a measure of outcome in trauma care, cost does not feature in either of these studies and has featured little in the literature. Functional and quality of life outcomes are also frequently stated as high priority for trauma systems research, however, only one of the studies evaluating the impact of trauma system implementation has considered this. For systems currently under development or approaching implementation,
consideration should be given to collecting long-term functional outcome data before system implementation to better evaluate trauma system effectiveness.

Quite what ‘it’ is that makes a system work is still to be elucidated. There are undoubtedly a multitude of factors at work, and identifying those that have the biggest impact on patient outcome is of great importance.

Authors’ conclusions
At this time, having considered the included observational studies and other evidence that did not meet our inclusion criteria, there is insufficient high quality evidence to support major change within health services to reorganise the provision of trauma care to implement regional systems.

Implications for practice
Based on the currently available evidence, no firm conclusions on the effectiveness of inclusive trauma systems can be made. Severely injured patients may receive a mortality benefit from treatment within an inclusive trauma system but findings should be interpreted cautiously as studies examining this outcome were at high risk of bias. As only one of the included observational studies examined the effect on patients functional outcome or quality of life, it may be that reduced mortality is translated into increased levels of severe disability.

Implications for research
Authors should be encouraged to be more specific when they submit research for publication in the area of trauma systems or centres. There is huge discrepancy in systems as to what features it contains and these should be made more explicit when describing the study. This will allow more robust comparison between types of system in the future.

Even though a RCT randomising patients to trauma system vs. non-trauma system care is unlikely to be undertaken, it is feasible to implement high quality controlled before and after
studies. With the changes to trauma care in England currently underway, opportunities exist to take advantage of this opportunity and to carry out such a study.

As the quality of available evidence that trauma systems work is weak and not necessarily generalisable to the UK as a whole, further study in this regard is indicated. In the next chapter I will outline the research methods that will enable me to undertake both qualitative and quantitative studies to explore the effect of implementing inclusive trauma systems in two regions of England. This work will add to the knowledge base around such systems and, hopefully, help clinicians and commissioners in making decisive steps in improving trauma care both here, in the UK, and around the world.
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Chapter 3:
Research Methods
In the previous chapters I described the epidemiology of major trauma, the structure and provision of NHS care for those seriously injured in the UK and highlighted some of the concerns regarding national variability of care and patient outcomes. I introduced the concept of a trauma system and how they have been used by health providers in other countries with the aim of reducing mortality and morbidity in this population. I presented a systematic review of the evidence analysing the effect of implementing inclusive trauma systems which demonstrated that the quality of such evidence was very poor. However, trauma systems have nonetheless been implemented throughout England and in this chapter I will present the quantitative and qualitative methods that I will use to address the following study aim and objectives;

**Study aim**
To critically assess the implementation of inclusive trauma systems on processes and outcomes of care in two regions of England.

**Study objectives**

Objective 1: To outline the general pattern of trauma and the demographics of the population injured within two regions of England and a comparator region

Objective 2: To analyse the strength of association between changes in the commissioning and delivery of trauma care and changes in patient outcomes

Objective 3: To evaluate if process measures, previously deemed to be quality indicators, have changed since the introduction of regional trauma systems

Objective 4: To explore the views of NHS emergency department staff on the reorganisation of regional trauma care, any perceived risks or benefits of such change and, to explore the importance of individual processes with a trauma system

Objective 5: To provide recommendations to improve the operational effectiveness of current trauma systems and in the implementation of any future system
In order to achieve the aim of this study I will undertake a series of studies using both quantitative and qualitative methods. These will be described in further detail later in this chapter. I will first outline the type and overall design of the studies that will be used to fulfill each objective. I will then describe the populations that will be studied and the justification for this.

Study number: Study one

Links to: Objective 1 - To outline the general pattern of trauma and the demographics of the population injured within two regions of England and a comparator region

Study type: Observational, retrospective, database

Study location: Greater London, Greater Manchester, South Wales (Control)

Data source: United Kingdom Office for National Statistics (ONS) – Deaths

Background: To study the burden of trauma deaths in the study regions and to ‘set the scene’ of the scale of the potential problem. Data will be collected over a ten year time-frame and include the period’s before, during and after implementation of regional trauma systems. The ONS collect data from death certificates and information will be gathered on the age and gender of those killed as well the place of death (in hospital or out of hospital). Data will allow a population wide analysis.

Study number: Study two

Links to: Objective 1: To outline the general pattern of trauma and the demographics of the population injured within two regions of England and a comparator region

Objective 2: To analyse the strength of association between changes in the commissioning and delivery of trauma care and changes in patient outcomes

Objective 3: To evaluate if process measures, previously deemed to be quality indicators, have changed since the introduction of regional trauma systems

Study type: Comparator before and after study

Study location: MTC’s (only) in Greater London and Greater Manchester. Controlled with major hospitals in South Wales as no formal trauma system in place
Data source: Trauma Audit and Research Network

Background: Data will be extracted from the TARN database to provide anonymised information relating to injured patients who presented to Major Trauma Centre’s only, in the two year period immediately before designation and the two year period immediately after designation. Information relating to injury type and severity, clinical outcomes and hospital process measures will be collected and reported. The two regions will be compared to a comparator region (South Wales) that does not have a formal trauma system in operation, allowing to correct for any temporal trends.

Study number: Study three

Links to: Objective 2: To analyse the strength of association between changes in the commissioning and delivery of trauma care and changes in patient outcomes

Objective 3: To evaluate if process measures, previously deemed to be quality indicators, have changed since the introduction of regional trauma systems

Study type: Retrospective time-series analysis.

Study location: Greater London and Greater Manchester. All trauma receiving hospitals

Data source: Trauma Audit and Research Network database

Background: Data will be extracted from the TARN database to provide anonymised information relating to injured patients presenting to hospitals before, during and after the implementation of the regional trauma system. Information relating to injury type and severity, clinical outcomes and hospital process measures will be collected and reported. All hospitals within each study region that submit data to TARN will be included in this analysis (rather than just MTCs as in study 2).

Study number: Study four

Links to: Objective 4: To explore the views of NHS emergency department staff on the reorganisation of regional trauma care, any perceived risks or benefits of such
change and, to explore the importance of individual processes with a trauma system

Study type: Qualitative

Study location: MTC’s, TU’s and NTRH’s in Greater London and Greater Manchester

Data source: Emergency department clinical staff (nurses and doctors)

Background: To provide a greater understanding and depth to the research, interviews with emergency department clinical staff will provide insight into the need for change, drivers and barriers of system implementation and functioning, whether trauma systems are perceived to benefit patients and, if so, what aspects of the system are fundamental to achieving this.

Study number: Study five

Links to: Objective 5: To provide recommendations to improve the operational effectiveness of current trauma systems and in the implementation of any future system

Study type: Merged quantitative and qualitative data sets

Study location: Greater London and Greater Manchester

Data source: Emergency department clinical staff, ONS, TARN

Background: Both data sets were analysed independently of one another. The findings from each component of the studies were then listed and common themes identified. The data were then merged into the relevant themes and explored to establish where findings agreed, offered complementary information on the same issue or appeared to contradict one another. The aim of integrating the data is to gain a multi-faceted insight into the broader research question around the effect of implementing trauma systems in two regions of England. Recommendations can then be made.

Study population

As has previously been described, regional trauma systems have been implemented in each English NHS region. Rather than studying the whole of England, two regions were chosen to
allow an in-depth analysis using both qualitative and quantitative methods. The two regions chosen in which to undertake the studies were Greater London and Greater Manchester. These were selected as they have historically provided TARN with consistently high levels of good quality data reporting. And, whilst they are both major urban conurbations, they also exhibit many differences, from the populations that they serve, the types of trauma experienced and the structure and implementation of their trauma systems (Table 2). The comparator region used was South Wales as it did not have a formal trauma system in place throughout the period of study. The qualitative study was undertaken in both Greater London and Greater Manchester. Before I describe the methods used in detail, I will describe these regions and their trauma care infrastructure.

Table 2: Regional characteristics of Greater London and Greater Manchester

<table>
<thead>
<tr>
<th></th>
<th>Greater London</th>
<th>Greater Manchester</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geography</strong></td>
<td>Urban</td>
<td>Mixture of urban and rural</td>
</tr>
<tr>
<td><strong>Trauma type</strong></td>
<td>More penetrating</td>
<td>Less penetrating, more falls</td>
</tr>
<tr>
<td><strong>Transport times to ED</strong></td>
<td>Short</td>
<td>Short to extended</td>
</tr>
<tr>
<td><strong>Initial investment to establish trauma system</strong></td>
<td>Investment provided for capital expenditure</td>
<td>Cost-neutral</td>
</tr>
<tr>
<td><strong>Implementation of system</strong></td>
<td>Immediate</td>
<td>Phased</td>
</tr>
<tr>
<td><strong>System processes</strong></td>
<td>24hr resident consultant cover</td>
<td>Initially, consultant resident 08.00-24.00. Changed to 24/7 December 2014</td>
</tr>
<tr>
<td><strong>TARN data submission</strong></td>
<td>High. Around 4000 cases pre-implementation and 6000 estimated to be in post-implementation group</td>
<td>High. Around 6000 cases pre-implementation and 8000 cases estimated to be in post-implementation group</td>
</tr>
</tbody>
</table>
Greater London

Greater London is a county in the south of England organised into 32 boroughs and the City of London, a major financial hub. It has a population of 8.8 million people who live in an area of 1572km$^2$, and this population is projected to rise to 10 million by 2031.\textsuperscript{1} The population is ethnically diverse with 37% being originally born in a foreign country\textsuperscript{1} and it is estimated that 27% of Londoners live in poverty after accommodation costs have been taken into account.\textsuperscript{2} Greater London is served by an impressive transport infrastructure including multiple railway stations (including Eurostar), two major airports and a major road tributary encircling the region (M25).

Greater London Trauma Network

Perhaps one of the drivers for the introduction of regional trauma systems in England was the report published in 2007 by Professor Ara Darzi – A Framework for Action.\textsuperscript{3} Professor Darzi was asked by NHS London to examine how London’s healthcare system needed to change over the next ten years. There were concerns that whilst there were examples of excellence in health care there were also stark inequalities in health outcomes across the region and that the quality and safety of patient care was not always as good as it could be.

A number of challenges for NHS London were identified, the most acute being London’s growing and ageing population, with the fastest growing age groups being the 40-64 age group and the over 85s. As the population ages, added demands are placed on the health economy. The population of London is also highly transient with over one million people commuting in and out of the city on a daily basis plus over thirteen million tourists visit the city every year.

One of the main conclusions of the report was that patients who suffered particular medical conditions such as heart attacks, stroke or were seriously injured should be treated in specialist centres around the capital. Whilst this would lead to care being centralised to fewer hospitals, it was envisaged that the quality of care would improve, as would outcome, when patients were increasingly seen by senior doctors who were experts in the field.\textsuperscript{3}
With particular regard to trauma, the report recommended that a trauma system should be put into operation within London that would integrate hospital and pre-hospital care to identify and deliver patients to a specialised trauma centre quickly and safely. Bypass protocols would be introduced to ensure that the most seriously ill would be taken direct to trauma centres instead of the closest hospital, as was currently the case. The report also provisionally suggested there should be three major trauma centres in London, including the Royal London Hospital that was felt to be functioning at the level of a major trauma centre already. The figure was derived from the Royal College of Surgeons’ recommendation that trauma centres should serve between one and three million people depending on population density.

**Trauma system structure**

Following publication of *Healthcare for London: a Framework for Action*, the Healthcare for London (HfL) programme was set up by NHS London and the City’s Primary Care Trusts (PCTs) to develop proposals and implement its recommendations. It was agreed that a trauma system should be implemented in London that would be composed of a number of trauma networks. The London Trauma Office, led by Dr Fionna Moore, was established to coordinate the development and implementation of the system and a public consultation was subsequently undertaken on these proposals. In July 2009, the decision was made to designate and fund three major trauma centres each being the ‘hub’ within its own trauma network. The three networks subsequently ‘went live’ on April 6th 2010 following external quality assurance processes.

The three Major Trauma Centres (MTC) were identified as:

- The Royal London Hospital (East London)
- King’s College Hospital (South East London)
- St George’s Hospital (South West London)

Charing Cross and the Royal Free Hospital also initially applied to function as a MTC but did not meet the designation criteria. There was concern that the lack of a MTC in North West London posed a significant risk as London Heathrow airport and Wembley Stadium would not
be supported. Also, the establishment of the London trauma system was based on a maximum ambulance journey time of 45 minutes. Mapping by the London Ambulance Service demonstrated that without a MTC in North West London, this target could not be met.

Consequently, a second round of applications was considered from University College and Imperial NHS trusts and whilst both applications met the designation criteria, St Mary’s hospital in Paddington was chosen as the North-West London MTC. This went live as a MTC 24/7 on 11th January 2011 following the establishment of a neurosurgical satellite service within the hospital, completing the four networks that currently make up the London trauma system (Figure 4). The Royal London Hospital was given the largest network, as it was deemed the most established centre prior to formal designation.

Figure 4. Map of London trauma network (from London Trauma Office annual report 2011)
Each MTC sits within a trauma network, linked with a number of trauma units. Some trauma networks extend outside of London with their respective trauma units lying outside the greater London boundary and these networks accept trauma patients from neighbouring Strategic Health Authorities (SHAs) where clinically appropriate.

**Trauma triage**

In order to ensure that injured patients were taken to the most appropriate centre, with those most seriously injured being taken directly to a MTC, the London Ambulance Service (LAS) introduced a new triage tool (Appendix 4). It is based on a tool developed by the American College of Surgeons that used a four-stepped (latterly five-stepped (Appendix 5)) approach based on physiological signs, anatomy of the injury, mechanism of the injury and other factors. Even triggering one of these steps would necessitate transport to a MTC. Telephone support is available to ambulance crews 24/7 through the LAS dispatch centre if they require assistance in deciding to which hospital to transport a patient or if they may require the Helicopter Emergency Medicine Service (HEMS).

The London HEMS was established in 1989 and is based at the Royal London Hospital in East London. The service can rapidly deliver a senior doctor and specially trained paramedic to injured patients who are believed would benefit from high level care from the outset. In April 2010, the service became operational 24/7 to coincide with the establishment of the London trauma system, with teams utilising a helicopter during the day and rapid response cars at night.

**Trauma Network performance**

TARN plays a significant role in enabling the performance of the network to be monitored. Each NHS trust that is part of the system submits data to TARN about the injured patients it has treated. There are a large number of data fields collected through the TARN electronic Data Collection and Reporting system (eDCR) of which the Injury Severity Score (ISS) is one component. In addition to the ISS, the eDCR enables the collection of data on processes that demonstrate potential changes to patient care, such as time to CT scan. TARN is discussed in further detail below. The London trauma clinical steering group also devised a set of
performance standards for the delivery of trauma care within the networks, such as the presence of a resident consultant to lead the trauma team at all times.

**Paediatrics**

Seriously injured children are taken to one of the city’s four MTCs as per adult patients as there are no stand-alone paediatric MTCs in Greater London. A paediatric triage tool was developed by LAS for those aged under twelve years (Appendix 5) whilst children aged over twelve are encompassed by the adult trauma triage tool.

**Funding**

Funds were made available by NHS London through a quality premium to drive forward change following the publication of *Healthcare for London: a Framework for Action*. This money was given to participating NHS trusts to allow them to prepare for MTC and TU designation and was used in various ways:

- Provision of a dedicated CT scanner adjacent to the Emergency Department at King’s College Hospital
- Development of a trauma surgery manual by the Royal London Hospital
- The provision of a heli-pad at St George’s Hospital

**Education and training**

The London Deanery funded the development of two courses to support medical staff in gaining the necessary skills required to manage a trauma patient and to lead a trauma team. The trauma team leader course was developed by the North-East London and Essex trauma network. The two South London Networks jointly produced the Trauma Team Member course. Both courses were implemented across the networks to ensure all staff involved in trauma resuscitation were trained.
Greater Manchester

Greater Manchester is a county of 1,277km² in the North-West of England and is comprised of ten metropolitan boroughs and includes the cities of Manchester and Salford. It has a diverse and multi-cultural population, 7.7% of which are foreign born. Greater Manchester is the third most populous English county after Greater London and the West Midlands with a population of 2.8 million who live in a mix of urban, suburban and rural locations. Whilst the region’s economy has grown in recent years, a recent report estimated that 620,000 people continued to live in poverty. Greater Manchester is home to two of the largest football stadiums in the UK and regularly hosts major national and international events and has a transient student population of over 100,000. The region has a well-developed transport infrastructure including a tram network, a number of railway stations and an international airport.

The Greater Manchester Trauma System

Following the introduction of the London trauma system, the NHS framework instructed each English region to produce a plan for the implementation of a regional trauma system by April 1st 2011 with it being fully operational by April 1st 2012. Historically, Greater Manchester did not have a 24/7 specialist major trauma service or co-ordinated trauma system. It was a general response service with injured patients simply routed to the nearest emergency department with secondary transfer to specialist services if required at a later stage. The region had disparate services with key specialties required for the provision of optimum trauma care (e.g. neurosurgery, burns and plastic surgery) spread across the three acute NHS trusts (Salford Royal, Central Manchester and University Hospital of South Manchester).

The North-West Clinical Reference Group also had a number of concerns:

- Services for major trauma did not meet quality standards of care
- Poor coordination meant the time to definitive care was unacceptably delayed
- Patients may not be transported to definitive care as receiving hospitals could refuse admission due to lack of beds
- Governance was thought to be poor in some centres
• Inefficiencies in the use of expertise and resources

Consequently, the North-West Trauma Clinical Reference Group was asked to consider a number of options for the optimum delivery of a regional trauma system.

The model was required to provide strong organisational alignment for the successful strategic delivery of the new system, with improved service quality and leadership and assurance of strong governance to guarantee quality, patient outcomes and the balancing of service and financial benefits and risks.

As there was no NHS Trust within the region that provided all of the specialist services that are required in a MTC and extra resources were not available to reconfigure services, it was decided that the system should be delivered via a partnership of NHS trusts linked by a coordinating system of communication, shared governance and management. The proportional dominance of neurosciences and neurosurgery in the capability for managing major trauma and for patient survivability was accepted and this was the focus for network development.

A number of regional Trauma Units (TU) would also be designated to receive trauma patients and would work in formal partnership with a MTC. They would perform a 'staging post' function for patients with transport times >45 minutes and for those with catastrophic injuries needing to be stabilised prior to rapid transfer to a MTC.

**Trauma system structure**

The Greater Manchester Major Trauma Network covers the population of Greater Manchester. Following consensus between the three acute NHS trusts and the North-West Ambulance Service (NWAS) to form a major trauma system collaborative, the SHA agreed the plan for three MTCs (Manchester Royal Infirmary, Salford Royal and University Hospital of South Manchester), three TUs; Royal Oldham, Stepping Hill and Wigan, five local Emergency Departments, one children’s hospital that functioned as a paediatric MTC and one ambulance service, North-West Ambulance Service (Figure 5).
Figure 5: Greater Manchester Major Trauma Network (from April 2012 – October 2017)

The system went ‘live’ on Monday 16th April 2012 but had a phased implementation. Consequently, phase one operated between 0800-1700 Monday to Friday, phase two was implemented from Monday 20th August and operated from 0800-1700 all week with phase three of the system providing full time functionality introduced on Monday 14th January 2013. It was thought that a phased introduction would be a pragmatic approach to the system reorganisation and would enable demand to be assessed at the MTCs.

Initially, each MTC employed a consultant Trauma Team Leader (TTL) to be available in the Emergency Department between 08.00 and midnight, and to be within thirty minutes of the hospital when on call, if required. Within two years of system implementation, both Salford Royal and Manchester Royal Infirmary offered resident consultant TTL cover day and night, seven days a week.

Trauma Triage

The NWAS use a major trauma ‘Pathfinder’ triage tool that identifies patients with potential major trauma and allows for bypass to a MTC within 45 minutes (Appendix 7). NWAS created a ‘trauma cell’ alongside the air ambulance desk that is staffed by advanced paramedics who can advise crews about the most appropriate destination for a patient and also notified the MTC
or TU that a patient is en route to them, enabling the hospital to activate its major trauma team in readiness of the patient.

Patients were transported to the centre that was envisaged would best meet their clinical needs, if they were stable enough. Consequently, it was planned that patients with head injuries were taken to Salford Royal Hospital which houses the regional neurosurgical service, patients with severe burns were transported to the designated burns centre at UHSM and those with isolated chest injuries were taken to MRI or UHSM where cardio-thoracic surgery facilities were based. During the course of this study, this situation remained. However, in August 2016, changes were made to the system whereby UHSM was only designated to receive major trauma between the hours of 08.00 – 00.00 and in October 2017, MTC status was formally removed from the hospital leaving Manchester Royal Infirmary and Salford Royal as the two regional MTCs.

As in Greater London, the Greater Manchester is covered by an air ambulance service (North-West Air Ambulance) that is based out of Barton aerodrome to the west of the city. Its function is to reach, treat and transfer patients as quickly as possible to hospitals that can offer definitive care. Up until August 2016, care was predominately delivered by paramedics and ‘junior’ doctors, however, it now delivers consultant led care to the patient. As opposed to Greater London, the service is not available at night.

**Trauma network performance**

Trauma network performance is assessed based primarily on data submitted to TARN from each of the trauma receiving hospitals. TARN submissions have historically been very good from hospitals in the North West. Data is reviewed quarterly both by TARN and by the Greater Manchester trauma commissioning group.

**Paediatrics**

Greater Manchester is fortunate to have a stand-alone children’s hospital (Royal Manchester Children’s Hospital) based on the Manchester Royal Infirmary site in the city-centre. All paediatric surgical specialties are based at this site and it has an Emergency Department with on-site consultant cover from 08.00-00.00 seven days a week. A resident consultant TTL is
available overnight and should be in attendance within thirty minutes of being called. There is a well-established North-West and North Wales paediatric Transfer Service (NWTS) that is commissioned to transfer critically injured children from district general hospitals to specialist centres and is staffed by consultants with a special interest in paediatric retrieval medicine.

**Funding**

The introduction of the Greater Manchester trauma network was meant to be cost-neutral. In comparison to London, no extra resources were made available from NHS bodies outside of the individual NHS trusts involved.

**Education and training**

TTLs throughout the network were encouraged to attend a regional Trauma Team Leader course. Whilst nursing and medical staff at trauma receiving hospitals were also supported to attend courses such as the European Trauma Course (ETC) and Advanced Trauma Nursing Course (ATNC), no extra resources were made available to provide external education. Regular internal trauma education events at individual hospitals and at a network level were organised.

**South Wales**

South Wales was chosen to be a comparison region for one of the quantitative studies as it had no formal trauma system in place throughout the duration of the study. Consequently, temporal trends could be examined when comparing process and patient outcome measures following trauma system implementation in the two other study regions, Greater London and Greater Manchester. Data submission to TARN from South Wales has historically been excellent, especially from the University Hospital of Wales in Cardiff and Morriston Hospital in Swansea, two large hospitals that are experienced in treating large volumes of major trauma patients and which have most surgical specialties on site. Morriston hospital is the home of the Welsh national burns unit whilst neurosurgery, the regional Paediatric Intensive Care Unit (PICU) and an advanced rehabilitation service are based in Cardiff. Whilst most seriously injured patients in North and Mid Wales have been transferred to English NHS trauma systems for definitive trauma care, those injured in south Wales would be taken to their nearest ED, irrespective of
the services available. Following an expert review in 2017 of plans to implement an inclusive trauma system in south Wales, University Hospital of Wales was recommended to become a MTC with Morriston becoming a large TU.
Quantitative Methods

Study One

Office for National Statistics mortality data

The epidemiology of trauma deaths in Greater London, Greater Manchester and South Wales over time in terms of age, gender and location will be presented, analysing data obtained from the UK Office for National Statistics (ONS). The purpose of this work is to;

1. Understand the groups most vulnerable to death after injury in the three study regions by age and gender, and to;

2. Understand the proportions of trauma deaths amenable to healthcare (not certified dead at the scene) and if this changes over time.

This study will enable me to fulfill Objective 1: To outline the general pattern of trauma and the demographics of the population injured within two regions of England and a comparator region.

The ONS were asked to provide the number of deaths with secondary cause of death attributed to ICD-10 codes that relate to traumatic injury (All S codes and T0-32 (inclusive), T71, T75, T75.1 and T75.4). These were further sub-divided into sex (male/female) and ten-year age bands (e.g. 0-9, 10-19) for each year between 2006 and 2014. Deaths were reported by the place of death (Table 3) and the regional post-code area where the death occurred. These postcode areas, defined below, corresponded to the catchment areas of the regional trauma networks in the case of Greater Manchester and Greater London and the catchment area of the hospitals in South Wales that was used as the comparison region.

Greater London: All BR1-7, CR0-5, CR8, DA1, DA14-17, DA5-8, E1, E10-18, E2-9, EC1-4, EN1-5, HA0-9, IG1-3, IG11, IG6, IG8, KT1-4, KT6, KT9, N1, N10-22, N2-9, NW1-11, RM1-14, SE1-28, SM2-7, SW1, SW10-19, SW1A-9, SW20, TN14, TN16, TW1, TW3-5, TW7-14, UB1-10, W1-13, WC1, WC2 postcodes.
Greater Manchester: All M, BL and OL postcodes and SK 1-12 (inc.), WA13-15 (inc.) postcodes.

South Wales: All CF, NP, SA postcodes.

Table 3: Office for National Statistics table of definitions for place of death

<table>
<thead>
<tr>
<th>Place of Death</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td>Deaths at home are those at the usual residence of the deceased (according to the informant), where this is not a communal establishment.</td>
</tr>
<tr>
<td>Elsewhere</td>
<td>Elsewhere includes all places not covered above such as deaths on a motorway; at the beach; climbing a mountain; walking down the street; at the cinema; at a football match; while out shopping; or in someone else’s home. This category may also include people who are pronounced dead on arrival at hospital.</td>
</tr>
<tr>
<td>Hospital</td>
<td>Hospitals includes NHS general hospitals and multi-function sites, maternity hospitals, private hospitals and military hospitals.</td>
</tr>
<tr>
<td>Other communal establishment</td>
<td>Other communal establishments include holiday homes and hotels; common lodging houses; aged persons’ accommodation; assessment centres; schools; convents and monasteries; nurses’ homes; university and college halls of residence; young offender institutions; secure training centres; detention centres; prisons and remand homes.</td>
</tr>
<tr>
<td>Care home</td>
<td>Care homes includes homes for the chronic sick; nursing homes; homes for people with mental health problems and non-NHS multi-function sites.</td>
</tr>
<tr>
<td>Hospice</td>
<td>Hospices include Sue Ryder homes; Marie Curie centres; oncology centres; voluntary hospice units; and palliative care centres.</td>
</tr>
</tbody>
</table>

The TARN database only includes data on deaths within hospital. As it is recognised that many injured patients die before reaching hospital, including a description of pre-hospital deaths is especially important. The ONS is the only national body that collects such data.

For each region, I will present the ONS data in the following order:
- Number of deaths per year from 2006 – 2014
- Proportion of deaths in each ten-year age category, subdivided into sex
- Number of deaths in each ‘Medical’, ‘Home’ or ‘Elsewhere’ ONS category by age and sex
- Number of deaths per year in each of ‘Medical’, ‘Home’ and ‘Elsewhere' place of death. Age adjusted rates will also be presented using mid-year regional population estimates from the ONS.

Following on from study one where I presented ONS data to describe the pattern, epidemiology and location of trauma deaths in three regions of England, I then conducted an observational analyses, using trauma registry data, to assess patient outcome and process measures, prior to, during and following the implementation of a regional trauma system in Greater London and Greater Manchester.

**Study two: Comparator before and after study**

A comparator before and after analysis where each region that implemented a trauma system (Greater London and Greater Manchester) will be compared to a region, over the same time-frame, that has not implemented such a system (South Wales). Only those hospitals designated as MTC’s (on functioning in that capacity in South Wales) will be included.

Patient outcomes and process measures in the experimental regions will then be compared to the comparator region that does not yet have an inclusive trauma system to highlight any temporal trends. The adult and paediatric (≤16 years) population will be analysed separately but using the same methods.

Study two will help to fulfill the following objectives:

Objective 1: To outline the general pattern of trauma and the demographics of the population injured within two regions of England and a comparator region

Objective 2: To analyse the strength of association between changes in the commissioning and delivery of trauma care and changes in patient outcomes
Objective 3: To evaluate if process measures, previously deemed to be quality indicators, have changed since the introduction of regional trauma systems

Study three: Time-series analysis

The time series analysis incorporated data submitted to TARN from all hospitals within each region, rather than solely the MTC’s, as is the case with the comparative before and after study described below (study three). Consequently, this study looks at process measures and outcomes across the whole regional health system rather than just specialist centres. The adult and paediatric (≤16 years) population will be analysed separately but using the same methods.

Study three will help fulfill the following objectives:

Objective 2: To analyse the strength of association between changes in the commissioning and delivery of trauma care and changes in patient outcomes

Objective 3: To evaluate if process measures, previously deemed to be quality indicators, have changed since the introduction of regional trauma systems

The Trauma Audit and Research Network (TARN)

Data collection

Following an injury, patient demographics, observations and results are written within ambulance service documentation, emergency department notes and further clinical notes as patients progress through the hospital system. Increasingly, such notes are electronic. When patients are subsequently discharged from an acute hospital, the notes are coded for audit and payment purposes. At this point, trauma patients are identified and the notes passed to the local TARN data coordinator who will then assess whether the patient meets the following TARN inclusion criteria:

- Patient arrives at hospital alive within 24hrs of injury
- In-hospital death within 30 days of admission
- Intensive or high dependency care required
• Inter-hospital or specialist care required
• Hospital treatment for three or more days needed

Data are then collected by a local TARN data coordinator at each hospital and inputted into an eCDR. This is generically designed so that data on interventions, observations, investigations, surgical procedures and the seniority of clinicians treating the patient can be recorded. Since a trauma patient may be treated in different clinical settings (e.g. pre-hospital, TU, MTC), the system design allows data entry from any one of these locations and subsequent record linkage using unique patient identifiers.

TARN staff who have been trained in injury coding then classify injuries using the Abbreviated Injury Scale (AIS)\(^{14}\) and record the anatomical severity of injuries using the Injury Severity Score (ISS).\(^{15}\) ISS is defined as the sum of the squares of the AIS of each of the patient’s three most severe AIS injuries, regardless of the body region in which they occur. Outcome is assessed in terms of in-patient mortality at discharge or 30 days, whichever occurs first.

For the purposes of this study, the paediatric population (patients aged \(\geq 16\) years) has been analysed separately, as the structure of paediatric trauma services and the patho-physiology of paediatric trauma vary considerably from those of adults.\(^{13}\) Isolated closed limb fractures (excluding femoral shaft fractures), isolated facial injuries and simple spinal strains were excluded by TARN, as were isolated fractures to the neck of femur and pubic rami in those aged over 65 years.

The following data were extracted from the TARN database:

**Patient characteristics**

• Age
• Sex
• Geographical location where treated
Injury characteristics

- Mechanism e.g. fall, stabbing
- Body region injured
- Injury Severity Score (ISS)
- Abbreviated Injury Score (AIS)

Characteristics of pre-hospital phase

- Patient’s mode of arrival to the ED (e.g. self-presented, ambulance, Helicopter Emergency Medical Service (HEMS))
- Time, day, month and year of arrival of service to patient
- Transfer of severely injured patients direct to MTC

Characteristics of acute hospital phase

- Time, day, month and year of arrival
- Level of initial hospital (e.g. TU or MTC)
- Activation of trauma team
- Level of most senior doctor to initially assess patient in ED
- Requirement for CT scan
- Time to CT scan from arrival in ED
- Requirement for surgery
- Time to surgical intervention from arrival in ED
- Time to any secondary transfer for definitive care

Outcome characteristics

- Length of hospital stay
- Requirement for intensive care and, if necessary, length of stay
- Survival to discharge or mortality if within 30 days post injury, whichever is earlier
- Development of complications e.g. pneumonia
Study population

The study population will include all injured adult patients who meet TARN inclusion criteria and are initially treated in hospitals that now form part of either the Greater London or Greater Manchester regional trauma system. Data will be collected on patients treated from two years prior to implementation of the trauma system (from April 1st 2008 in London, April 16th 2010 in Manchester) through to two years post implementation (March 31st 2012 in London to April 15th 2014 in Manchester).

Primary outcome measure

The primary study outcome measure will be changes in risk adjusted odds of survival at 30 days in an interrupted time series analysis within each trauma system = “delta S”. Delta S with 95% confidence limits will be calculated, as will the significance of any trend. These statistics will be compared between Greater London and Greater Manchester and the comparison region.

Secondary outcome measures

The TARN data set will be scrutinised for the following process of care markers to compare annual performance within each system. As per Donabedian’s conceptual model that is used to evaluate the quality of health care, the NHS is changing the structure of trauma care which is postulated to change processes with the intent of improving outcome. However, in order for a process indicator to be valid it must previously have been demonstrated to produce improved outcomes.

- Proportion of seriously injured patients (ISS ≥15) initially transported to a MTC. The purpose of introducing regional field triage protocols for ambulance crews is to aid the identification of those seriously injured and ensure their rapid transfer to a MTC for definitive care. Receiving early definitive trauma care has been shown to reduce mortality and morbidity.

- Proportion of seriously injured patients (ISS ≥ 15) managed completely outside an MTC. In an inclusive trauma system this should not happen. As outlined above, such patients should be triaged to be taken immediately to a MTC or, in the transport time is
more than 45 minutes or the patient is too unstable, then they should be taken to a TU, stabilised and then transferred to a MTC without delay.

- Median hospital and Intensive Care Unit (ICU) length of stay. Seen as a surrogate marker of hospital efficiency by the NHS and longer length of stays have been associated with increased risk of complications and reduced patient satisfaction.¹⁸

- Proportion of patients receiving consultant delivered care from arrival in ED. Trauma patients seen initially by senior, experienced medical staff have been shown to have improved outcomes.¹⁹

- Median time to Computed Tomography (CT) scan. The benefit of CT in imaging major trauma patients is well established and the sooner this is undertaken following the arrival of a patient to the ED, the sooner accurate diagnoses can be made and appropriate action taken e.g. surgery.²⁰

- Median time to surgery. Many trauma patients suffer time critical injuries and there is evidence from many surgical specialties (e.g. neurosurgery and general surgery) that operating on such patients early on improves outcome.²¹,²²

- Development of complications. Used as a marker of quality of care, hospital acquired complications have been demonstrated to increase morbidity, mortality and hospital length of stay.²³

**Statistical analysis**

All statistical analysis will be performed using the Statistical Package for Social Sciences (SPSS, version 21, Chicago, Il). Continuous variables were compared using unpaired t tests for normally distributed data and Mann-Whitney U tests for non-normally distributed data. Confidence intervals were calculated for proportions. Statistical significance was set for P values of less than 0.050.

Standardised risk adjusted excess rates of survival (Ws) were calculated for all groups but patients transferred to other centres were excluded as their final outcome was unknown. Ws is a standardised version of the W statistic which represents the excess number of survivors per 100 cases and is defined as $W = 100 \times \left(\frac{\text{observed number of survivors} - \text{expected number of survivors}}{\text{number of cases}}\right)$.
survivors) / total number of patients]. Expected survival was determined using the sum of the probability of survival predicted by the risk-adjusted model used in TARN. The covariates used within this model were age, gender, Glasgow Coma Scale, ISS and the Charlson Comorbidity Index, which is a weighted comorbidity score commonly used in observational studies.\textsuperscript{24}

**Data quality**

The number of injured patients submitted to the Trauma Audit & Research Network database for each region and study period was compared to the number of patients identified in the ONS Hospital Episode Statistics (HES) dataset that appear to meet the TARN inclusion criteria for the same period. A case ascertainment percentage was then calculated for each region or group of hospitals. Poor data completeness was a potential risk factor for introducing selection bias into the studies. It was planned that if it was identified that individual regions or hospital types (e.g. TUs) had poor data completeness then an analysis would be carried out of all the data regardless of data completeness (primary analysis), compared to only hospitals with high quality data completeness (> 65%) (sensitivity analysis).

**Data security**

TARN data are securely hosted upon a dedicated server at the University of Manchester computer centre. To ensure data security, Secure Sockets Layer (SSL) certificates have been integrated into the system. SSL is a leading security protocol on the internet and is widely used to validate the identity of web sites and create an encrypted connection for sending personal data. To further strengthen security, data remain in an encrypted format within the database. The National Computing Centre performs bi-annual penetration tests on TARN computer systems to ensure data protection.

Any data downloaded from the TARN database for the purposes of this study was collected, stored, analysed and disposed of in accordance with the regulations of the University of Manchester under the UK Data Protection Act 1998. Data will be stored in an encrypted format and at all times will remain anonymous.
**Ethical approval**

TARN has been granted approval, via the National Information Governance Board (NIGB), for section 251 of the NHS Act 2006 that allows TARN to hold certain patient identifiers (approval number: PIAG3-04 (e)/2006). Section 251 allows common law duty of confidentiality to be set aside in specific circumstances where anonymised information is not sufficient and where patient consent is not practicable. This approval is reviewed annually by the NIGB.

**Study number four**

**Qualitative Study**

Whilst carrying out an analysis of quantitative data from the ONS and TARN can be used to measure change and outcomes over time, this data could not provide us with insights into the setting of a problem, an understanding of underlying reasons and motivations, or uncover prevalent trends in thought and opinion. For these reasons, and to provide a more complete and comprehensive understanding of the research problem, it was thought important to employ a mixed-methods evaluation of the two regions that have implemented trauma systems. A sequential explanatory study design was used, where collection and analysis of quantitative data preceded the collection and analysis of qualitative data. Following recruitment of a purposive sample of NHS employees who have been involved in the development, implementation and/or provision of care within two regional trauma systems in England, qualitative methods were used to explore their perceptions on the impact of introducing a trauma system and to explore the drivers and barriers to successful implementation and operation.

I will determine any correlation between qualitative perceptions of change in trauma care versus actual measurable changes in process and outcome in a quantitative analysis. Although with an observational study it is not possible to infer causation, it is possible to comment using mixed methods on apparent strengths of association between changes in process and changes in outcome.
This study will allow me to fulfill objective number four: To explore the views of NHS emergency department staff on the reorganisation of regional trauma care, any perceived risks or benefits of such change and, to explore the importance of individual processes within a trauma system.

Setting
The study will record the views of NHS Emergency Department staff based in two regions of England: Greater London and the Greater Manchester. These two regions have been described in detail above and have been chosen for the following reasons:

- It will allow comparison with quantitative data gained from the same regions as part of the study. Triangulation of TARN, ONS and the qualitative data will be important in enhancing the reliability of the results and assessing the attainment of qualitative data saturation
- The two regions are diverse in terms of geography, population distribution, transport times to hospital and the type of trauma encountered
- They are at different stages of maturity (the Greater London trauma system was introduced two years before Greater Manchester)
- The implementation of London’s trauma system received additional funding whilst the Greater Manchester system was planned to be ‘cost-neutral’
- Greater Manchester used a ‘staged’ approach to implement its trauma system, initially only active between 9-5 Monday-Friday whilst London’s system was immediately available 24 hours a day, seven days a week from its introduction.

Participants
The study was conducted between July 2015 and January 2016. To allow the study objectives to be met, members of the sample were required to demonstrate particular characteristics that will enable detailed exploration and understanding of the central themes. Participants had to be current NHS staff who have been involved in the development and implementation of the Greater London or Greater Manchester regional trauma system or have a clinical role in providing care to those treated within either of these systems. Clinical staff were required to be
At consultant level, if a doctor, or to be at least band six level if a nurse, and to have worked within an emergency department prior to implementation of the trauma system to allow collection of data about experiences before, during and after. Apart from selection criteria relating to experience and geographical location, it was also necessary to explore the views of staff working in different environments with at least one senior doctor and senior nurse recruited from an emergency department within each of a MTC, TU and hospitals that do not formally receive trauma patients following system implementation, in each region.

Whilst this strategy meant that at least twelve interviews were undertaken, this was thought necessary to cover the potentially broad spectrum of views within emergency departments that now had different roles within the trauma system. Ultimately, however, the total number of interviews was determined by the point at which data saturation is reached. Data saturation is said to be attained when there is no new data or themes, further coding is no longer feasible and when there is enough information to replicate the study.\(^{25}\) A saturation grid was developed and completed as interviews progressed with cross-referencing to field notes.\(^{26}\) At the point data saturation was believed to be attained, formal data coding commenced and an updated data saturation grid was completed. Further interviews were planned to be undertaken if data saturation had not been reached.

Participants were selected using the qualitative sampling technique of ‘snowballing’.\(^{27,28}\) This technique utilises well informed individuals to identify fellow participants who are believed to have experience and information about the topic in question. It is a type of non-probability sampling. Through my work as an emergency department doctor in Greater Manchester, carrying out research at TARN and having initially trained in London, I was aware of a key person in each region who had been instrumental in implementing each trauma system and would be aware of ‘key’ participants in their region who would meet the study inclusion criteria and be well placed to offer useful insight.

I approached the identified individual in writing to inform them about the research project. I provided an information leaflet (Appendix 8) outlining the study and asking them to participate.
in a single semi-structured interview and explaining what participation would entail and their rights as a participant in the study. They were asked to return a reply slip (Appendix 9) indicating if they would be willing to take part in an interview. If they indicated that they were willing to take part, they were contacted by telephone and verbally provided with information detailing what participation will entail, their rights, and were provided with the opportunity to ask questions. Those still willing to take part were consented for participation during the interview (Appendix 10).

At the end of each interview I asked the participant if they would identify further participants who met the study inclusion criteria. As the first participant recruited to both sample groups provided multiple referrals, an exponential non-discriminative snowball technique was used.

**Data Collection**

Face to face interviews took place at a time and venue convenient for the staff member and were expected to last up to 60 minutes. The outcome of the recruitment process, including the characteristics of those who declined to take part, was recorded.

Semi-structured interviews were chosen as the data-gathering method of choice, as this method allowed participants to think about and answer freely about their own experiences and perspectives. Semi-structured interviews strike a balance between a structured interview and unstructured interview. In semi-structured interviews the questions are open ended and do not limit the participants choice of answers. The purpose was to provide a setting/atmosphere where the interviewer and participant could discuss the topic in detail. I was therefore able to make use of cues and prompts to help and direct the interviewee into the research topic area, thus being able to gather a more in depth and detailed data set. The interviews were directed by a topic guide (Appendix 11).

The initial interviews tested the scope of the topic guides and enabled their ‘piloting.’ Following the first three interviews, I met with my supervisory team to review the topic guide, enabling me to refine it prior to the bulk of the interviews and to assess the duration of interviews and the time spent on each key topic. Data from these pilot interviews was included in the analysis.
Interviews were digitally audio-recorded (Olympus DS-3500) and encrypted with the participants’ permission and transcribed verbatim. I transcribed the first two interviews whilst the remaining interviews were transcribed by an external company authorised by the University of Manchester.

Data Analysis

Transcripts were analysed thematically using framework analysis, a manual, matrix method, which has been shown to facilitate thematic and cross-case interpretation.

Framework analysis is a qualitative method that is aptly suited for this research. Developed by two qualitative researchers, Jane Ritchie and Liz Spencer in 1994, framework analysis can be said to be quite similar to grounded theory; however, framework analysis differs in that it is better adapted to research that has specific questions, a limited time frame, a pre-designed sample (e.g. professional participants) and a priori issues (e.g. organisational and integration issues) that need to be dealt with. Although framework analysis may generate theories, the prime concern is to describe and interpret what is happening in a particular setting.

Analysis proceeded in five stages:

- **Familiarisation**: Transcripts were read and re-read to familiarise and immerse myself in the data.
- **Identification of the thematic framework**: A meeting was held with my supervisors to discuss and identify key issues, concepts and themes arising from the data, and to group them thematically to construct a conceptual framework.
- **Indexing**: I applied the thematic framework to the same transcript to explore any differences in application. The thematic framework was then applied systematically to all the data.
- **Charting**: I constructed thematic matrices for all identified categories/sub-categories to further summarise and synthesise the indexed data.
- **Detection, categorisation and classification**: The original research questions were reconsidered and the charts examined in order to define concepts, map the range and nature of phenomena, find any associations and provide explanations.
Data were organised and analysed using NVIVO 10 software (QSR International, Victoria, Australia).

Field-notes were also completed during and following each interview. This allowed me the opportunity to record what I experienced outside the immediate context of the interview, thoughts about the dynamic of the interview and any issues that may be relevant to the analytical stage.

A copy of the study findings was sent to participants and comments invited.

**Study 5**

**Synthesis of quantitative and qualitative data**

The aim of integrating the data was to gain a multi-faceted insight into the broader research question around the effect of implementing trauma systems in two regions of England. The integration of qualitative and quantitative data has been shown to increase the value of mixed methods research and provide more information than ‘the sum of its parts’.

However, many mixed methods studies do not integrate these data sets despite a number of different techniques to aid such a task, such as the triangulation protocol and the mixed-methods matrix, being described. In this study I used the technique of ‘merging’.

Both the quantitative and qualitative data sets were initially analysed independently of one another using techniques associated with the primary data type and the findings presented. The integrity of each data set was therefore preserved. The findings from each component of the study (systematic review, ONS data (study 1), TARN analyses (study 2+3) and the qualitative analysis (study 4) were then listed in a matrix and common themes identified. The data were then merged into the relevant themes and explored to establish where findings agreed, offered complementary information on the same issue, appeared to contradict one another or remained ‘silent’.

The synthesis of the study findings produced seven main themes and these are presented in the discussion chapter.
This study will enable me to fulfill Objective 5: To provide recommendations to improve the operational effectiveness of current trauma systems and in the implementation of any future system.

**Data protection**

Data were collected, stored, analysed and disposed of in accordance with the regulations of the University of Manchester and the Data Protection Act 1998. Data were stored in an encrypted format and at all times will remain anonymous. Research governance best practice was followed as detailed by the Medical Research Council.\(^{34}\)

**Ethical approval**

Following discussion with the University of Manchester ethics committee, National Research Ethics Service (NRES) and a local NHS research and development department, it was felt that a formal ethics committee application was not necessary as the study solely investigated NHS staff views on service evaluation by virtue of their employment. Local Research and Development office approval was sought prior to interviewing staff members at NHS facilities.
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Chapter 4: Quantitative results
In the previous chapter, the methods that would allow me to critically assess the implementation of inclusive trauma systems on processes and outcomes of care in two regions of England were described. In this chapter, the quantitative results are presented. Firstly, the epidemiology of trauma deaths in Greater London, Greater Manchester and South Wales (the comparator region) over time in terms of age, gender and location are presented, analysing data obtained from the UK Office for National Statistics (ONS). The purpose of this work was to:

- Understand the groups most vulnerable to death after injury in the three study regions by age and gender, and to;

- Understand the proportions of trauma deaths amenable to healthcare and if this changed over time.

Following on from this analysis, two further observational analyses are presented, using trauma registry data, to assess patient outcome and process measures, prior to, during and following the implementation of a regional trauma system in two English regions. Changes in the experimental regions were compared to changes in the comparator region that did not have an inclusive trauma system.

These two analyses were delineated as follows:

- **Study 2**: A comparative before and after analysis of MTCs where each region that implemented a trauma system (Greater London and Greater Manchester) will be compared to a region, over the same time-frame, that has not implemented such a system (South Wales)

- **Study 3**: An observational time-series analysis of all hospitals in Greater London and Greater Manchester regions annually from two years before trauma system implementation to two years following its implementation
The adult and paediatric (≤16 years) population were analysed separately but using the same methods.

**Study 1: Office for National Statistics Mortality Data**

The Office for National Statistics (ONS) provided mortality data on both study regions (Greater London and Greater Manchester) along with the control region, South Wales. Data were supplied for the period from 1st January 2006 to 31st December 2014 (calendar year) allowing any trends to be assessed over a number of years before and after trauma system implementation.

Data was sub-divided into deaths by region, year, ten-year age groups, gender and place of death. The reported place of death was either in hospital (‘Medical’), at home (‘Home’) or out of hospital, such as on a road at the site of a vehicular collision or pronounced dead on arrival at hospital (‘Elsewhere’). These ONS definitions are further described in the Methods chapter.

The purpose of presenting the ONS data was to allow comparison with data from the UK Trauma Audit and Research Network (TARN) and to present a population view of trauma deaths in each region over time. Importantly, the TARN database only includes hospital deaths if the patient dies there within 30 days of injury and does not include deaths that occur outside of hospital (i.e. those in the ONS ‘Home’ and ‘Elsewhere’ categories). Having an understanding of the proportions of trauma patients who die in these different locations could be important in measuring pre-hospital care medical services and injury prevention strategies in the regions that implemented trauma systems.

Using mid-year population estimates from the ONS, crude mortality rates for each of the three regions were calculated and these are presented in Figure 6. Whilst rates in all three regions remained relatively stable, Greater London demonstrated consistently less trauma deaths than the other two regions and also showed a gradual fall in trauma deaths from 19.5/100,000 in 2006 to 15.3/100,000 in 2014. In comparison, Greater Manchester recorded a trauma death
rate of 27.7/100,000 in 2006, this peaked to 31.4/100,000 in 2009 but otherwise remained stable with 28.6 trauma deaths per 100,000 in 2014. South Wales demonstrated the highest crude mortality rate from trauma, except for 2009 and 2011. The rate peaked at 35.1/100,000 in 2007 and reached its lowest point of 25.8/100,000 in 2014.

![Graph showing number of trauma deaths per 100,000 population by region and year](image)

**Figure 6:** Number of trauma deaths per 100,000 population by region and year

The proportion of injured patients who died in hospital remained relatively stable in all three regions over the study period, however, a consistently greater proportion of patients died in hospital in Greater Manchester than in Greater London or South Wales (Figure 7). In Greater Manchester, each year, at least 65% of patients died in hospital reaching a peak of 68.8% in 2009 with a nadir of 62.4% in 2008. South Wales demonstrated more peaks and troughs with 61.1% dying in hospital in 2014 compared to 49.3% in 2011. The proportion of trauma deaths in hospital was more stable over time in Greater London, falling from 62.9% in 2006 to 56.5% in 2014.

To explore some of the differences in crude mortality in different regions and the observation that between 30-50% of seriously injured patients are dying outside of hospital, further analyses of the ONS data by region are presented.
Greater London

There were 12,591 deaths attributed to trauma in Greater London between 01/01/2006-31/12/2014, of these 8253 were male (65.5%) and 4338 (34.5%) were female. Figure 8 shows the number of deaths per year for both male and female groups. The highest annual number of deaths occurred in 2008 (1497) with the fewest deaths in 2013 (1229). The proportion of male to female deaths remained around 2:1 each year over the nine-year period.

The Greater London trauma network was introduced in March 2010 and there were 1453 deaths that year. This was followed by a fall in the number of deaths year on year until 2014 when the number of trauma deaths rose again to 1309.

Figure 7: Percentage of trauma patients who die in hospital by year and by region
Figure 8: Number of deaths per year in Greater London due to trauma

Figure 9 demonstrates the proportion of deaths in each age category. Overall, the majority of trauma deaths occurred in the 80-89 year age group (2231 (17.7%)), followed by the 20-29 year age group (1681 (13.4%)) with the fewest occurring in the 0-9 year age group (164 (1.3%)).

Figure 9: Proportion of deaths from trauma in Greater London between 2006-14 per age group
However, further subdividing the data into male and female reveals differences in the proportion of deaths in each age group dependent on gender. This is shown in Figures 10 and 11 below. In the male group, the highest number of trauma deaths occurred in the 20-29 age group (646) followed by those in the 30-39 year group (525). In fact, 51% (4245) of male trauma deaths occur in the 10-49 year age groups. The fewest number of deaths were in the 0-9 year category (104).

![Figure 10: Proportion of male deaths from trauma in Greater London by age group between 2006-14](image)

With regards to female trauma deaths, the greatest proportion occurred in the 80-89 age group (1151(26.5%)), followed by the 90+ group (888(20.5%)). Consequently, nearly 50% of deaths occurred in those over 80 years. Deaths in those aged 0-9 years comprised the smallest group over the period (60(1.4%)).
Over the nine year period in London, 7190 trauma deaths took place within the hospital environment, (57%) compared to 2820 (22.3%) deaths ‘elsewhere’ and 2581 deaths at ‘home’ (20.5%). However, as Table 4 demonstrates, the number of people who died in each location changes with age category and gender.

Most male deaths in those aged 20-59 years were out of hospital, with 646 (48.4%) deaths in males aged 20-29 occurring ‘elsewhere’ (e.g. at the scene of an accident/assault) and with the largest proportion of deaths at ‘home’ occurring in the 50-59 year age group (363(36.2%)). It is not until the 60-69 age group (excluding the 0-9 group) that most male trauma deaths occur in hospital and the proportion then steadily increases with age.
Table 4: Place of death secondary to trauma according to age group and gender

<table>
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<tr>
<th>Age group</th>
<th>Gender</th>
<th>Place of death</th>
<th>Total</th>
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<td></td>
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<td>0-9</td>
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</table>

With regards to female deaths, overall most occurred in hospital (3056(70.4%)). However, in the 20-59 age groups, as with men, most deaths secondary to trauma occurred outside hospital. The greatest number of deaths ‘elsewhere’ occur in the 20-29 year group (112 (32.4%)) whilst the greatest number of deaths at ‘home’ occur in the 30-39 year group (127(40.1%)). As age progresses, so does the proportion of female deaths in hospital (888(93.4%)) in the 90+ group). Year on year, the proportion of deaths in each location does not seem to have changed greatly (Figure 12).
Prior to the introduction of the Greater London trauma network in 2010, the proportion of deaths ‘elsewhere’ was 23.9% (358) and 23.2% (325) in the years 2008 and 2009 respectively. Following its introduction, this proportion fell to 21.2% (308) in 2010 and 22.4% (319) in 2011. This fall has continued with the exception of 2012 where it increased to 24.8% (324).

The proportion of deaths in hospital fell steadily from 62.8% (929) in 2006 to 53.8% (703) in 2012 but has increased since to 56.5% (740) in 2014. The greatest proportion of deaths at ‘home’ occurred in 2013 (282(22.9%)) with its nadir in 2007 (218 (14.7%)).

**Greater Manchester**

There were 6776 deaths attributed to trauma in Greater Manchester between 01/01/06 and 31/1/2/14, of these 3970 were male (58.5%) and 2812 (41.5%) were female. Figure 13 shows the number of deaths per year for both male and female groups. The highest annual number of deaths occurred in 2009 (826) with the fewest deaths in 2006 and 2007 (both 709). The proportion of male to female deaths has remained around 3:2 each year over the nine-year period.
The Greater Manchester trauma network was introduced in May 2012 and there were 738 deaths that year. This was followed by an increase in the number of deaths year on year with 747 deaths in 2013 and 781 deaths in 2014.

![Figure 13: Number of deaths per year in Greater Manchester due to trauma](image1)

Figure 13: Number of deaths per year in Greater Manchester due to trauma

Figure 14 demonstrates the proportion of deaths in each age category. Overall, the majority of trauma deaths occurred in the 80-89 year age group (1705 (25.2%)), followed by the 90+ year age group (987 (14.6%)) with the fewest occurring in the 0-9 year age group (67 (1%)).

![Figure 14: Proportion of deaths from trauma in Greater Manchester between 2006-14 per age group](image2)

Figure 14: Proportion of deaths from trauma in Greater Manchester between 2006-14 per age group
However, further subdividing the data into male and female, reveals differences in the proportion of deaths in each age group dependent on gender. This is shown in Figures 15 and 16 below. In the male group, the highest number of trauma deaths occurred in the 80-89 age group (689(17.4%)) followed by those in the 40-49 year group (554(14%)). Overall, 43% (1706) of male trauma deaths occur in the 10-49 year age groups. The fewest number of deaths were in the 0-9 year category (36(1%)).

![Figure 15: Proportion of male deaths from trauma in Greater Manchester by age group between 2006-14](image)

With regards to female trauma deaths, the greatest proportion occurred in the 80-89 age group (1016(35.1%)), followed by the 90+ group (725(25.8%)). Consequently, over 60% of deaths occurred in those over 80 years with only 13.4% (377) occurring in the 10-49 year age groups. Deaths in those aged 0-9 years comprised the smallest group over the period (31(1.1%)).
Over the nine-year period in Greater Manchester, the majority of trauma deaths took place within the hospital environment (4564, 67.4%) compared to 912 (13.5%) deaths 'elsewhere' and 1300 deaths at 'home' (19.2%). However, as Table 5 demonstrates, the number of people who die in each location changes with age category and gender.

Most male deaths in those aged 20-59 years were out of hospital (1318(67.1%)), with 175 (34.6%) deaths in males aged 20-29 occurring ‘elsewhere’ and with the largest proportion of deaths at ‘home’ occurring in the 40-49 year age group (226(40.3%)). It is not until the 60-69 age group (excluding the 0-9 and 10-19 age groups) that most male trauma deaths occur in hospital and the proportion then steadily increases with age.
Table 5: Place of death secondary to trauma according to calendar year and sex

<table>
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<th>Place of death</th>
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<td>M</td>
<td>10</td>
<td>49</td>
<td>630</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>8</td>
<td>45</td>
<td>963</td>
</tr>
<tr>
<td>90+</td>
<td>M</td>
<td>2</td>
<td>16</td>
<td>244</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>1</td>
<td>13</td>
<td>711</td>
</tr>
<tr>
<td>Total</td>
<td>M</td>
<td>779</td>
<td>968</td>
<td>2223</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>133</td>
<td>332</td>
<td>2341</td>
</tr>
</tbody>
</table>

With regards to female deaths, overall most occur in hospital (2347(83.5%)). However, in the 20-59 age groups, as with men, most deaths secondary to trauma take place outside hospital (263(66.4%)). The greatest number of deaths ‘elsewhere’ occur in the 40-49 year group (29 (23.4%)) whilst the greatest number of deaths at ‘home’ occur in the 30-39 year group (55 (44.4%)). As age progresses, so does the proportion of female deaths in hospital (711 (98.1%) in the 90+ group).

Year on year, the proportion of deaths in each location does not seem to have changed greatly (Figure 17).
Prior to the introduction of the Greater Manchester trauma network in 2012, the proportion of deaths ‘elsewhere’ was 14.2% (102) and 12.5% (94) in the years 2010 and 2011 respectively. Following its introduction, this proportion fell to 12.1% (89) in 2012 but has increased since to 13.4% (100) in 2013 and 13.3 % (104) in 2014.

The proportion of deaths in hospital has remained between 65%-70% over the nine years with its peak in 2008 (552((69.4%) falling to 508 deaths (65%) in 2014. The greatest proportion of deaths at ‘home’ occurred in 2014 (169 (20.5%)) with its nadir in 2009 (150 (18.2%)).

South Wales
There were 5837 deaths attributed to trauma in the South Wales study region between 01/01/2006 and 31/12/2014, of these 3616 were male (61.9%) and 2221 (38.1%) were female. Figure 18 shows the number of deaths per year for both male and female groups. The highest annual number of deaths occurred in 2007 (743) with the fewest deaths in 2006 (596). The proportion of male to female deaths has remained around 3:2 each year over the nine-year period.
Figure 18: Number of deaths per year in South Wales due to trauma

Figure 19 demonstrates the proportion of deaths in each age category. Overall, the majority of trauma deaths occurred in the 80-89 year age group (1309(22.4%)), followed by the 70-79 year age group (691(11.8%)) with the fewest occurring in the 0-9 year age group (40(0.7%)).

Figure 19: Proportion of deaths from trauma in South Wales between 2006-14 per age group
However, further subdividing the gender categories into male and female reveals differences in the proportion of deaths in each age group dependent on gender. This is shown in Figures 20 and 21 below. In the male group, the highest number of trauma deaths occurred in the 40-49 age group (541(15%)) followed by those in the 80-89 year group (533(14.7%)). In fact, 45.4% (2010) of male trauma deaths occur in the 10-49 year age groups. The fewest number of deaths were in the 0-9 year category (25(0.7%)).

**Figure 20:** Proportion of male deaths from trauma in South Wales by age group between 2006-14

With regards to female trauma deaths, the greatest proportion occurred in the 80-89 age group (776(34.9%)), followed by the 90+ group (497(22.4%)). Consequently, 57.3% of deaths occurred in those over 80 years. Deaths in those aged 0-9 years comprised the smallest group over the period (12(0.5%)).
Over the nine-year period in South Wales, the majority of trauma deaths took place within the hospital environment (3314, 57%) compared to 1191 (20.4%) deaths ‘elsewhere’ and 1332 deaths at ‘home’ (22.8%). However, as Table 6 demonstrates, the number of people who die in each location changes with age category and gender.

Most male deaths in those aged 10-69 years were out of hospital (1729(47.8%)), with the highest proportion of deaths ‘elsewhere’ (e.g. at the scene of an accident/assault) in the 10-19 age group (127(50.8%)) and with the largest proportion of deaths at ‘home’ occurring in the 40-49 year age group (276(40.3%)). It is not until the 70-79 age group (excluding the 0-9 group) that most male trauma deaths occur in hospital and the proportion then steadily increases with age.
Table 6: Place of death secondary to trauma according to calendar year and gender

<table>
<thead>
<tr>
<th>Age group</th>
<th>Gender</th>
<th>Place of death</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Elsewhere</td>
<td>Home</td>
</tr>
<tr>
<td>0-9</td>
<td>M</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>10-19</td>
<td>M</td>
<td>96</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>31</td>
<td>10</td>
</tr>
<tr>
<td>20-19</td>
<td>M</td>
<td>216</td>
<td>127</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>32</td>
<td>35</td>
</tr>
<tr>
<td>30-39</td>
<td>M</td>
<td>169</td>
<td>144</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>27</td>
<td>32</td>
</tr>
<tr>
<td>40-49</td>
<td>M</td>
<td>197</td>
<td>228</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>36</td>
<td>48</td>
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<tr>
<td>50-59</td>
<td>M</td>
<td>152</td>
<td>173</td>
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<td></td>
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<td>29</td>
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<td>60-69</td>
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<td>70-79</td>
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<td>5</td>
<td>65</td>
</tr>
<tr>
<td>90+</td>
<td>M</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td>M</td>
<td>1001</td>
<td>981</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>190</td>
<td>351</td>
</tr>
</tbody>
</table>

With regards to female deaths, overall most occur in hospital (1679(75.6%)). However, in contrast to both Greater London and Greater Manchester where more women died outside of hospital in the younger age groups, in South Wales, the proportion of women who die in hospital is consistently greater than those who die out of hospital in each year studied. The greatest proportion of deaths ‘elsewhere’ occurred in the 10-19 year group (31 (50.8%)) whilst the greatest proportion of deaths at ‘home’ occurred in the 40-49 year group (48 (40.3%)). The greatest proportion of female deaths in hospital was seen in the 90+ group (474 ((95.3%)). Year on year, the proportion of deaths in each location is demonstrated in Figure 22 below.
Figure 22: Number of trauma deaths in South Wales by year with subdivision into place of death

Over the nine-period, the proportion of deaths ‘elsewhere’ varied between a peak of 24.6% (147) in 2011 and 17% (116) in 2013. The proportion has been below 20% since 2012. The proportion of deaths in hospital peaked in 2007 at 60.7% (451) then fell each year reaching a nadir of 49.3% (295) in 2011. Since then it has increased again to 60.4% (366) in 2014. The greatest proportion of deaths at ‘home’ occurred in 2013 (204 (29.9%)) with its nadir in 2007 (139 (18.4%)).

Synopsis

The ONS data were used to provide a background to the epidemiology of trauma deaths in the study regions. Crude mortality rates remained relatively static and they were noticeably consistently lower in Greater London compared to Greater Manchester or South Wales. Most trauma deaths were men with Greater London having a greater proportion of male to female deaths (2:1) compared to the other regions (3:2). The majority of deaths were in the ≥80 year age groups in all regions, although most male deaths occurred in much younger age categories, compared to females.
The data show that, over this time-frame, in all three regions around 30-50% of injured patients die outside of hospital. In fact, the majority of deaths in younger men (10-69 year age groups) occurred out of hospital in all three regions, with 48% of 20-29 year olds who were killed in Greater London dying outside of home or hospital. In Greater London and Greater Manchester this trend continued with the female population with most deaths in the 20-59 age groups occurring out of hospital. In South Wales, however, this was not the case with the proportion of women dying in hospital consistently greater than those deaths out of hospital.

The data show that whilst trauma can affect anyone, the majority of patients who died in these regions were elderly, particularly so in the female population. Also, many patients die before they can benefit from hospital delivered care. In the Discussion chapter I will discuss the ramifications of these results in the context of current evidence but I will now present data obtained from TARN to analyse the effect of trauma system implementation on the populations described above.

**Study two: Comparator before and after study**

This analysis of the TARN data compares patients treated in MTCs only in both Greater London and Greater Manchester with data of patients treated in equivalent hospitals in South Wales. South Wales was chosen as a control region as it currently does not have a formal trauma system. Consequently, any temporal trends may be highlighted. Data were collected from all regions from two years prior to the introduction of the trauma system to two years after.

Following an assessment of data quality from South Wales, during the period of study, only two hospitals (University of Wales Hospital in Cardiff and Morriston Hospital in Swansea) provided TARN with high levels of case ascertainment compared to that expected by Hospital Episode Statistics (HES) data. Both of these hospitals were large, university teaching hospitals with multiple specialist surgical services and could fulfill a role of MTC, as confirmed by a recent report into the re-organisation of trauma care in Wales. Therefore, it was decided to compare equivalent hospital types in each region over time. The analysis of each region will be examined separately, as will both their paediatric and adult populations.
To reiterate, the variables that address the primary study outcome measure will be changes in risk adjusted odds of survival at 30 days in an interrupted time series analysis within each trauma system. These statistics will be compared between Greater London and Greater Manchester and the comparison region.

Secondary outcome measures include:

- Proportion of seriously injured patients (ISS ≥15) initially transported to a MTC
- Proportion of seriously injured patients (ISS ≥15) managed completely outside an MTC
- Median hospital and Intensive Care Unit (ICU) length of stay
- Proportion of patients receiving consultant delivered care from arrival in ED
- Median time to Computed Tomography (CT) scan
- Median time to surgery
- Development of complications

Statistically significant results will be annotated in the tables with a * and highlighted in bold in the text. All p values and 95% confidence intervals are reported and no mathematical correction has been made for multiple comparisons.

**Children (South Wales, Greater London, Greater Manchester)**

The number of number of cases submitted to TARN for children treated at a MTC in Greater London increased from 215 to 294 (37%) in the two years following trauma system implementation (Table 7) compared with a smaller increase seen in the control region (137 to 142 (4%)). Whilst in both regions the majority injured were males, the median age increased from 8.9 years to 10.7 years in Greater London in the after group (p=0.009, t-test) whilst in South Wales the median age fell from 10.6 years to 9.1 years over the same time-frame (p=0.0394, t-test). There was no significant change in Mechanism of Injury (MOI) over time in either group though the proportion of injuries secondary to falls <2 metres was greater in South Wales (29% vs 11%), although falls from >2 metres were more common in Greater London, as were penetrating injuries. The median ISS was greater in children treated in Greater London
(13 before, 16 after) compared to South Wales (9 before, 9.5 after), though the change over time was not found to be statistically significant.

The number of cases submitted to TARN for injured children from Greater Manchester and South Wales (equivalent) MTCs increased from 61.5% (187 to 302 cases) and 79.7% (138 to 248 cases) respectively over the study period (Table 7). Whilst the majority were male in both regions, the median age was slightly higher in South Wales than in Greater Manchester and also showed a statistically significant fall between the before and after group from 11 to 7.5 years ($p=0.0005$, t-test). The mechanism of injury profile was similar between the regions although there were proportionally more falls from height (>2 metres) in Greater Manchester than in South Wales (13.9%-16% vs 4.4%-10.1%). The median ISS was also similar between both regions with South Wales having a median ISS of between 9-9.5 and Greater Manchester having a median score of 10-9.5. Neither mechanism of injury or median ISS showed any statistically significant change between the before and after groups in either region.

<table>
<thead>
<tr>
<th>MOI</th>
<th>South Wales Before</th>
<th>South Wales After</th>
<th>Greater London Before</th>
<th>Greater London After</th>
<th>Greater Manchester Before</th>
<th>Greater Manchester After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall &lt;2m [%]</td>
<td>41 (29.9)</td>
<td>41 (28.9)</td>
<td>23 (10.7)</td>
<td>38 (12.9)</td>
<td>59 (31.6)</td>
<td>108 (35.8)</td>
</tr>
<tr>
<td>Fall &gt;2m [%]</td>
<td>16 (11.7)</td>
<td>5 (3.5)</td>
<td>49 (22.8)</td>
<td>46 (15.6)</td>
<td>30 (16)</td>
<td>42 (13.9)</td>
</tr>
<tr>
<td>Blow [%]</td>
<td>12 (8.8)</td>
<td>18 (12.7)</td>
<td>10 (4.7)</td>
<td>22 (7.5)</td>
<td>18 (9.6)</td>
<td>14 (4.6)</td>
</tr>
<tr>
<td>MVC [%]</td>
<td>49 (35.8)</td>
<td>57 (40.1)</td>
<td>88 (40.9)</td>
<td>134 (45.6)</td>
<td>46 (24.6)</td>
<td>91 (30.1)</td>
</tr>
<tr>
<td>Stabbing [%]</td>
<td>-</td>
<td>21 (9.8)</td>
<td>34 (11.6)</td>
<td>2 (1.1)</td>
<td>3 (1)</td>
<td></td>
</tr>
<tr>
<td>Crush [%]</td>
<td>-</td>
<td>2 (1.4)</td>
<td>3 (1.4)</td>
<td>2 (0.7)</td>
<td>2 (1.1)</td>
<td>3 (1)</td>
</tr>
<tr>
<td>Firearm [%]</td>
<td>3 (2.2)</td>
<td>-</td>
<td>6 (2.8)</td>
<td>4 (1.4)</td>
<td>0</td>
<td>2 (0.7)</td>
</tr>
<tr>
<td>Other [%]</td>
<td>16 (11.7)</td>
<td>19 (13.4)</td>
<td>15 (7.7)</td>
<td>14 (4.8)</td>
<td>30 (16)</td>
<td>39 (12.9)</td>
</tr>
</tbody>
</table>

Table 7: Patient and injury characteristics of children in South Wales, Greater London and Greater Manchester (* denotes statistical significance before vs after)

The number of children seen in hospital between 00.00 and 08.00 for major trauma was low in both regions and fell following trauma system implementation in Greater London from 14% to 11.2% (95% CI 3.6-10.7, 7.9-15.4). However, it also fell in the control region from 9.6% to 7.1%
Whilst those initially seen by a consultant increased from 64.8% to 91.8% in Greater London (95% CI 5.7-7.2, 8.8-9.5) there was no change in the control group (95% CI 41.2-65.7, 54.3-76.8). Whilst time to CT scan fell in both regions from 3 to 2.5 hours in South Wales and from 1.1 to 0.7 hours in Greater London, neither change was statistically significant. The proportion of children that underwent CT scanning increased in both regions from 43.1% to 44.4% in South Wales (95% CI 34.6-51.8, 36-53) and from 60% to 68.4% in Greater London (95% CI 53.1-66.6, 62.7-73.6).

A greater proportion of children presented ‘out of hours’ (00.00-08.00) in Greater Manchester compared to South Wales (12.6%-16% vs 7.6-9.4%) (Table 8). Initial consultant involvement in care increased in South Wales (from 53-56%, 95% CI 41.2-65.7, 47.7-64.2) although to a greater extent in Greater Manchester (38.9% to 73.7%, 95% CI 29.1-49.5, 68-78.9). The proportion of children requiring a CT scan also increased from 41.3-44.8% (95% CI 38.5-51.2, 33.7-50.7) in South Wales and from 35.8-49.3% in Greater Manchester where the increase was statistically significant (95% CI 29.1-49.5, 68-78.9). Time to CT also fell significantly in Greater Manchester from 7hrs to 0.9hrs (p=0.004, t-test) between the before and after group. A smaller fall was also seen in South Wales from three hours to 2.4 hours, although this was not statistically significant. In comparison to adult patients, the proportion requiring surgery increased (49.3%-54.4% South Wales vs 38.5%-42.1% Greater Manchester) as did the median time to surgery (23.1-23.8hrs South Wales vs 14.1-15.3hrs Greater Manchester), although these increases were not statistically significant.

Whilst total hospital LOS fell in Greater London from seven days to five days following trauma system implementation, the control region LOS remained at seven days. However, ICU LOS remained similar between the two regions with no change over time whilst a greater proportion of children required critical care in Greater London (47.3% vs 35.9% in South Wales). The proportion of patients developing complications increased from 5.6% to 8.8% (95% CI 2.9-9.5, 5.9-12.7) in the Greater London group following implementation whilst in South Wales there was no change (8.5%) over this time. Crude mortality fell in both regions from 2.9% to 2.1% in
South Wales (95% CI 8.7-10.7, 3.1-8.7).

There was no statistically significant change over time between the before and after groups in either Manchester or Wales with regards to outcome. Median LOS fell following trauma system implementation in Greater Manchester from eight to six days although median LOS on critical care increased from two to three days, neither change was statistically significant. Whilst complications increased over time in South Wales from 7.2% to 10.5% (95% CI 3.5-12.9, 7-15), they fell in Greater Manchester MTCs from 11.2% to 0.3% (95% CI 0.1-1.8, 0.7-16.7). However, crude mortality increased in both regions from 2.2% - 3.2% (95% CI 0.5-6.2, 1.4-6.3) in South Wales and from 1.1% to 2% (95% CI 0.1-3.8, 0.7-4.3) in Greater Manchester, although the actual numbers remained very low.

Table 8: Process and outcome measures of children in South Wales, Greater London and Greater Manchester (* denotes statistically significant between before vs after group)

<table>
<thead>
<tr>
<th></th>
<th>South Wales</th>
<th>Greater London</th>
<th>Greater Manchester</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Presented OOH [n (%)]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>13 (9.6)</td>
<td>10 (7.1)</td>
<td></td>
</tr>
<tr>
<td>After</td>
<td>10 (7.1)</td>
<td>11 (8.9)</td>
<td></td>
</tr>
<tr>
<td><strong>Consultant input [n (%)]</strong></td>
<td>37/67 (55.4)</td>
<td>103/159 (68.4)</td>
<td>234/255 (91.8)*</td>
</tr>
<tr>
<td>Before</td>
<td>30 (14)</td>
<td>33 (11.2)</td>
<td></td>
</tr>
<tr>
<td>After</td>
<td>30 (16)</td>
<td>38 (12.6)</td>
<td></td>
</tr>
<tr>
<td><strong>Number requiring CT [n (%)]</strong></td>
<td>59 (43.1)</td>
<td>129 (60)</td>
<td>201 (68.4)</td>
</tr>
<tr>
<td>Before</td>
<td>63 (44.4)</td>
<td>201 (68.4)</td>
<td></td>
</tr>
<tr>
<td>After</td>
<td>30 (16)</td>
<td>38 (12.6)</td>
<td></td>
</tr>
<tr>
<td><strong>Median time to CT [hours (IQR)]</strong></td>
<td>3 (1.6-19.7)</td>
<td>1.1 (0.6-1.9)</td>
<td>0.7 (0.4-1.4)</td>
</tr>
<tr>
<td>Before</td>
<td>2.5 (1-15.2)</td>
<td>7 (1-8)</td>
<td></td>
</tr>
<tr>
<td>After</td>
<td>2 (1-7)</td>
<td>7 (1-8)</td>
<td></td>
</tr>
<tr>
<td><strong>Number requiring surgery [n (%)]</strong></td>
<td>67 (48.9)</td>
<td>99 (54.2)</td>
<td>137 (46.6)</td>
</tr>
<tr>
<td>Before</td>
<td>73 (51.4)</td>
<td>201 (68.4)</td>
<td></td>
</tr>
<tr>
<td>After</td>
<td>30 (16)</td>
<td>38 (12.6)</td>
<td></td>
</tr>
<tr>
<td><strong>Median time to surgery [hours (IQR)]</strong></td>
<td>25.6 (3.9-69.3)</td>
<td>14.2 (3.3-44.6)</td>
<td>14.9 (2.6-26.4)</td>
</tr>
<tr>
<td>Before</td>
<td>18.9 (4.4-69.3)</td>
<td>14.2 (3.3-44.6)</td>
<td>14.9 (2.6-26.4)</td>
</tr>
<tr>
<td>After</td>
<td>139 (47.3)</td>
<td>139 (47.3)</td>
<td></td>
</tr>
<tr>
<td><strong>LOS [days (IQR)]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>7 (5-10)</td>
<td>7 (4-11)</td>
<td></td>
</tr>
<tr>
<td>After</td>
<td>7 (3-12)</td>
<td>5 (4-9)</td>
<td></td>
</tr>
<tr>
<td><strong>Complications [n (%)]</strong></td>
<td>12 (8.8)</td>
<td>12 (8.5)</td>
<td>26 (8.8)</td>
</tr>
<tr>
<td>Before</td>
<td>12 (8.5)</td>
<td>12 (8.5)</td>
<td></td>
</tr>
<tr>
<td>After</td>
<td>16 (5.4)</td>
<td>21 (11.2)</td>
<td></td>
</tr>
<tr>
<td><strong>Crude mortality [n (%)]</strong></td>
<td>4 (2.9)</td>
<td>4 (2.9)</td>
<td>6 (2)</td>
</tr>
</tbody>
</table>

Adults (South Wales, Greater London, Greater Manchester)

The number of cases submitted to TARN from Greater London adult patients increased 82% (2250 to 4086) following trauma system implementation whilst in South Wales the number fell from 1471 to 1358 cases over the same period (7.7%) (Table 9). Many more male patients were injured compared to females though the proportion was higher in Greater London (66% South
Wales vs 78% Greater London). However, the median age of those injured was higher in South Wales (51.5-52.1yrs) compared to Greater London (36.3-39.1yrs).

The number of cases submitted to TARN increased by 17.5% (1370 to 1610 cases) in South Wales and 124% (1269 to 2843) in Greater Manchester over this period (Table 9). Whilst there was no statistically significant change in patient demographic, mechanism of injury or injury severity in either region between the before and after groups, the proportion of males injured fell from 66.6% - 61% in South Wales and from 68.4% to 62% in Greater Manchester. The median age increased in both regions from 52.6 – 56.1yrs in South Wales and from 49.4 to 56.9 years in Greater Manchester. The injury profile was similar between both regions with most injuries due to falls, although a fewer proportion of patients were injured in MVCs in Greater Manchester (15.9%-18.4%) compared to South Wales (25.1%-25.2%). The median ISS remained the same in both regions increasing from 9 to 10.

With regards to mechanism of injury, a greater proportion were injured through falls from low height (<2 metres) in South Wales compared to Greater London (46.7-47.3% vs 8.4-12.9%) although injuries from higher falls (>2 metres) were greater in Greater London (23.2-21.9% vs 13.2-14%). Injuries sustained from MVCs were also higher in Greater London (41.3-39.1% vs 23.9-24.7%) as were penetrating injuries such as stabbings (12.1-12.2% vs 1.8-2.4%) and shootings (2.3-2.8% vs 0.2%). Injury severity was higher in Greater London with the median ISS being 16 compared to 9 in South Wales. Neither mechanism of injury or median ISS showed any statistically significant change between the before and after groups in either region.
### Table 9: Patient and injury characteristics of adults in South Wales, Greater London and Greater Manchester

<table>
<thead>
<tr>
<th></th>
<th>South Wales</th>
<th>Greater London</th>
<th>Greater Manchester</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td><strong>Demographic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>1471</td>
<td>1358</td>
<td>2250</td>
</tr>
<tr>
<td>Median age [years (IQR)]</td>
<td>51.5 (33.3-68)</td>
<td>52.1 (32.1-70.1)</td>
<td>36.3 (25.5-53.2)</td>
</tr>
<tr>
<td><strong>MOI</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall &lt;2m [n (%)]</td>
<td>696 (47.3)</td>
<td>631 (46.7)</td>
<td>189 (8.4)</td>
</tr>
<tr>
<td>Fall &gt;2m [n (%)]</td>
<td>194 (13.2)</td>
<td>190 (14)</td>
<td>521 (23.2)</td>
</tr>
<tr>
<td>Blow [n (%)]</td>
<td>162 (11)</td>
<td>120 (8.8)</td>
<td>139 (6.2)</td>
</tr>
<tr>
<td>MVC [n (%)]</td>
<td>351 (23.9)</td>
<td>335 (24.7)</td>
<td>929 (41.3)</td>
</tr>
<tr>
<td>Stabbing [n (%)]</td>
<td>26 (1.8)</td>
<td>33 (2.4)</td>
<td>275 (12.2)</td>
</tr>
<tr>
<td>Crush [n (%)]</td>
<td>6 (0.4)</td>
<td>22 (1.6)</td>
<td>10 (0.4)</td>
</tr>
<tr>
<td>Firearm [n (%)]</td>
<td>2 (0.2)</td>
<td>3 (0.2)</td>
<td>62 (2.8)</td>
</tr>
<tr>
<td>Other [n (%)]</td>
<td>34 (2.3)</td>
<td>24 (1.8)</td>
<td>125 (5.6)</td>
</tr>
<tr>
<td>Blunt:Penetrating</td>
<td>1438:338 (97.7:2.3)</td>
<td>1319:39 (97.1:2.9)</td>
<td>1902:348 (84.8:15.2)</td>
</tr>
<tr>
<td><strong>Injury severity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median ISS (IQR)</td>
<td>9 (9-17)</td>
<td>9 (9-17)</td>
<td>16 (9-20)</td>
</tr>
</tbody>
</table>

A greater proportion of adults than children presented between 00.00-08.00 and there was some increase in both regions between the before and after groups, although this was not statistically significant (18.2%-19.7% South Wales (95% CI 16.3-20.3-17.6-22) vs 22.9%-23.6% Greater London (95% CI 21.2-24.7, 22.3-25) (Table 10). In both South Wales and Greater London, the proportion of patients seen initially by a consultant increased significantly over time from 34.5%-47.4% in Wales (95% CI 31.3-37.7, 44-50.7) and from 61.6%-90.7% in London (95% CI 59.4-74.4, 89.8-91.7). The proportion of patients requiring CT increased in Greater London following trauma system implementation from 72.5% to 78.2% (95% CI 70.6-74.4, 76.9-72.5) and the time to CT fell (1.2hrs to 0.7hrs) (p=0.0107, t-test). Note that whilst the proportion of patients requiring a CT also increased in South Wales and the time taken to CT in South Wales also fell (from 3.8hrs to 3.5hrs) over the same time-frame, neither were statistically significant. With regards to surgery, the proportion requiring surgery also fell in Greater London MTCs (53.7%-49.6%, 95% CI 40.7-44.9, 48.1-51.2) although the median time to surgery actually increased from 12.5 hours to 15 hours (p<0.05, t-test). In South Wales, the proportion requiring surgery also fell (52.1%-48.7%, 95% CI 46-51.4, 49.6-54.7) but here time to surgery fell from 22.5 hours to 19.2 hours although this was not statistically significant.
Around 20% of patients were seen between 00.00 and 08.00 with the proportion falling slightly between the before and after groups in both regions (19.1%-18.8% (95%CI 17.1-21.3, 16.9-20.8) South Wales and 22.6% - 19.7% (95% CI 20.3-25, 18.2-21.2) in Greater Manchester (Table 14). Consultant input increased in both regions from 47 to 53% in South Wales (95% CI 44-50.6, 51.2-57.3) and from 28.9% to 60% (95% CI 58-61.9, 60.4-64) in Greater Manchester. The proportion requiring CT also increased from 55.3%-56.1% (95% CI 52.7-58, 53.7-58.6) in South Wales and 49.3%-65.1% (95% CI 63.3-66.8, 46.5-52.1) in Greater Manchester. The time to CT also fell in both regions from 3.4-2.1hrs in South Wales and from 3.1-1.2hrs in Greater Manchester (p=0.0037, t-test). The proportion requiring surgery was lower in Greater Manchester (48.8%-53.5% vs 40.1-38.7%) than in South Wales although there was no statistically significant change over time in either regions.

With regards to outcome, whilst both hospital and ICU LOS was lower in Greater London there was no change between the before and after groups, except there was a fall in the proportion requiring critical care (42.8%-40%, 95% CI 70.8-74.5, 38.5-41.5). In South Wales, hospital LOS fell from 11 to 10 days with ICU LOS falling from 5 to 4 days (p = 0.14, t-test). Whilst crude mortality was higher in Greater London (9%-10.3%, 95% CI 9-11.6, 8.1-9.9) compared to South Wales (6.3-6.4%, 95% CI 5.1-7.8, 5.2-7.8), there was no significant change between the before and after groups in either region. However, complications increased over time in both regions from 16.2%-19.7% in South Wales (95% CI 17.6-21.9, 14.4-18.2) and from 6.4% to 15.5% in Greater London (95% CI 9-11.6, 8.1-9.9).

With regards to outcome measures, there was no statistically significant difference between the before and after group in either region. However, the total hospital LOS was lower in Greater Manchester (falling from 8-7 days) compared to South Wales (increased from 10 to 11 days) and ICU LOS also fell in Greater Manchester following introduction of the trauma system from four to three days. The proportion of patients who developed complications was greater in South Wales but increased slightly in both regions over time (21.1%-22.2%, 95% CI 19-23.4, 20.2-24.3 in South Wales vs 6.9%-7.8% (95% CI 5.6-9.5, 6.8-8.8 in Greater Manchester). Overall, crude mortality also increased from 6.6% to 7.6% (95% CI 5.3-8, 6.3-9) in South Wales and
from 7.2% to 7.7% (95% CI 5.8-8.7, 6.8-8.8) in Greater Manchester, but was not shown to be statistically significant.

**Table 10**: Process and outcome measures of adults in South Wales, Greater London and Greater Manchester (* denotes statistically significant between before vs after group)

<table>
<thead>
<tr>
<th></th>
<th>South Wales</th>
<th>Greater London</th>
<th>Greater Manchester</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td><strong>Time of arrival</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presented OOH [n (%)]</td>
<td>268 (18.2)</td>
<td>268 (19.7)</td>
<td>516 (22.9)</td>
</tr>
<tr>
<td><strong>Procedures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consultant input [n (%)]</td>
<td>298/865 (34.5%)</td>
<td>415/876 (47.4%)*</td>
<td>1097/1777 (61.7%)</td>
</tr>
<tr>
<td>Number requiring CT [n (%)]</td>
<td>767 (52.1)</td>
<td>754 (55.5)</td>
<td>1632 (72.5)</td>
</tr>
<tr>
<td>Median time to CT [hours (IQR)]</td>
<td>3.8 (1.8-17.9)</td>
<td>3.5 (1.4-16.3)</td>
<td>1.2 (0.6-2.5)</td>
</tr>
<tr>
<td>Number requiring surgery [n (%)]</td>
<td>767 (52.1)</td>
<td>661 (48.7)</td>
<td>1209 (53.7)</td>
</tr>
<tr>
<td>Median time to surgery [hours (IQR)]</td>
<td>22.5 (6.7-60)</td>
<td>19.2 (6.1-48.6)</td>
<td>12.5 (3-40.7)</td>
</tr>
</tbody>
</table>

| **Outcome**          |             |                |                    |                    |                    |                    |
| LOS                  | 11 (5-22)   | 10 (5-21)      | 9 (4-19)           | 8 (4-18)           | 7 (4-11)           | 7 (4-11)           |
| Number requiring critical care [n (%)] | 363 (24.7)  | 352 (25.9)     | 963 (42.8)         | 1635 (40%)*        | 618 (21.7)         | 618 (21.7)         |
| Median LOS critical care [days (IQR)] | 5 (2-13)    | 4 (2-9)        | 3 (1-7)            | 3 (1-8)            | 3 (1-7)            | 3 (1-7)            |
| Complications [n (%)] | 239 (16.2)  | 267 (19.7)     | 143 (6.4)          | 633 (15.5%)*       | 221 (7.8)          | 221 (7.8)          |
| Crude mortality [n (%)] | 94 (6.4)    | 86 (6.3)       | 231 (10.3)         | 367 (9)            | 220 (7.7)          | 220 (7.7)          |

**Survival for adults and children**

Overall, standardised rates of survival for patients treated in MTCs in each region are depicted in Figure 23. The Ws score for Greater Manchester MTCs has improved from a nadir of -1.83 (95% CI -3.4 - -0.26) in 2011/12 to 1.09 (95% CI 0.21 – 1.96) in 2013/14. Greater London MTCs have also seen an improvement in the Ws score since trauma system implementation from – 0.81 (95% CI -1.8 – 0.56) in 2008/9 to 1.84 (95% CI 0.61 – 2.1) in 2012/13. South Wales MTC equivalent hospitals have not demonstrated such an obvious upward trend in Ws score, with a peak of 0.62 (95% CI -0.36 – 0.9) in 2010/11, falling to a nadir of -1.6 (95% CI -1.91 - -0.72) in 2012/13.
Figure 23: Standardised rate of survival of patients treated in MTCs only in London, Manchester and South Wales by year (Adults and children)

Synopsis
The number of trauma cases reported to TARN in all three areas increased over the study period, however, it was more marked in those regions that implemented formal trauma systems. Potential reasons for this change will be discussed in the following chapter. Overall, in all three regions the number of children affected was low, were mainly from falls but those injured in Greater London had a higher ISS. Since the introduction of MTCs in Greater London and Greater Manchester, a greater proportion of children were seen by a consultant on arrival and underwent CT scan. The time taken from arrival to CT also fell to a greater degree in such regions, compared to the South Wales.

In the adult population, most injuries were in males and also secondary to falls, although the proportion of penetrating injuries was higher in Greater London, as was the ISS of those injured. A younger population was affected there compared to South Wales. The proportion of injured patients imaged by CT showed a significant increase, as did the time taken from arrival to CT in the MTCs compared to the comparator region. Overall, standardised rates of survival
showed an upward trend in both Greater Manchester and Greater London demonstrating that more patients than expected were now surviving in the year’s following trauma system introduction. Such a change could not be shown in South Wales.

**Study three: Time series analysis**

The previous analysis of TARN data specifically focused on the change over time in MTCs only in both Greater London, Greater Manchester and a comparator region, South Wales. In this, the third analysis, TARN data from each of the two years prior to the introduction of the London trauma network on April 1st 2010 and the Greater Manchester trauma network on 16th April 2012, is presented along with each of the two years following system introduction. This analysis encompassed data submitted to TARN from all hospitals within each region, not only from MTCs, to enable a wider study of any effect of trauma system implementation on the population. As in the previous analysis, data are presented by region and the paediatric and adult populations are described separately.

To reiterate, the variables that address the primary study outcome measure will be changes in risk adjusted odds of survival at 30 days in an interrupted time series analysis within each trauma system. These statistics will be compared between Greater London and Greater Manchester and the comparison region.

Secondary outcome measures include:

- Proportion of seriously injured patients (ISS ≥15) initially transported to a MTC.
- Proportion of seriously injured patients (ISS ≥ 15) managed completely outside an MTC.
- Median hospital and Intensive Care Unit (ICU) length of stay.
- Proportion of patients receiving consultant delivered care from arrival in ED.
- Median time to Computed Tomography (CT) scan.
- Median time to surgery
- Development of complications
Statistically significant results will be annotated in the tables with a * and highlighted in bold in the text. All p values and 95% confidence intervals are reported and no mathematical correction has been made for multiple comparisons.

**Greater London children**

The number of submissions to TARN increased steadily from 171 in 2009/10 to 408 in 2012/13, representing an increase of 138% (Table 15). Many characteristics about the children remained similar over the four years with the median age ranging from 6.9 years (IQR 2.5-13) in 2009/10 to 8.4 years (IQR 2.4-13.8) in 2010/11. Around 70% of those injured each year were boys, with falls and motor vehicle collisions the leading cause of injury. However, whilst the proportion of injuries from motor collisions fell over time from 35.7% (95% CI 28.5-43.3) in 2008/9 to 28.2% (95% CI 23.9-32.8) in 2011/12, the only statistically significant change in mechanism of injury was seen in falls. The proportion of children injured through falls <2 metres increased from 22.2% (95% CI 16.2-29.2%) in 2008/9 to 41.4% (95% CI 36.6-46.4) in 2011/12 whilst those injured through falls >2 metres fell over time from 21.1% in 2008/9 (95% CI 15.2-27.9) to 8.6% (95% CI 6-11.7) in 2011/12. The median ISS was 9 throughout the four-year period with around 30% of injuries being classed as serious (ISS≥15). Whilst there was a fall in the proportion of children seriously injured from 41% (95% CI 33.5-48.7) in 2008/9 to 26.2% (95% CI 20.3-32.8) in 2009/10, it has since remained stable.

In 2008/9 33.9% (95% CI 26.9-41.5) of patients were transferred directly to a MTC and despite an increase to 53.4% (95% CI 46.3-60.4) in 2009/10, the proportion then fell back to 36.8% (95% CI 31.7-42.2) in 2010/11. The proportion of children requiring secondary transfer fell year on year from 29.8% (95% CI 23.1-37.3) in 2008/9 to 16.2% (95% CI 12.7-20.1) in 2011/12 (Table 16). A greater proportion of more severely injured children (ISS ≥15) were transported directly to a MTC following the introduction of the trauma system (50% (95% CI 37.8-62.2)) in 2008/9 compared to 65.8% (95% CI 56.6-74.2) in 2011/12 and were less likely to be treated entirely outside of a MTC (28.6% (95% CI 18.4-40.6)) in 2008/9 compared to 2011/12 (8.3% (95% CI 4.1-14.8)).
Table 15: Profile of paediatric major trauma patients in Greater London 2008-2012

<table>
<thead>
<tr>
<th>Patient characteristic</th>
<th>2008/9</th>
<th>2009/10</th>
<th>2010/11</th>
<th>2011/12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trauma patients [n]</td>
<td>171</td>
<td>206</td>
<td>342</td>
<td>408</td>
</tr>
<tr>
<td>Median age (years [IQR])</td>
<td>6.9 (2.5-13)</td>
<td>8.4 (2.4-13.8)</td>
<td>7.4 (2.4-13.4)</td>
<td>7.3 (2.4-13.2)</td>
</tr>
<tr>
<td>Male [n (%)]</td>
<td>116 (67.8)</td>
<td>150 (72.8)</td>
<td>228 (66.7)</td>
<td>286 (70.1)</td>
</tr>
<tr>
<td>Mechanism of injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall &lt;2m [n (%)]</td>
<td>38 (22.2)</td>
<td>59 (28.6)</td>
<td>116 (33.9)</td>
<td>169 (41.4)</td>
</tr>
<tr>
<td>Fall &gt;2m [n (%)]</td>
<td>36 (21.1)</td>
<td>27 (13.1)</td>
<td>44 (12.9)</td>
<td>35 (8.6)</td>
</tr>
<tr>
<td>Blunt assault [n (%)]</td>
<td>7 (4.1)</td>
<td>11 (5.3)</td>
<td>23 (6.7)</td>
<td>34 (8.3)</td>
</tr>
<tr>
<td>Vehicle incident/collision [n (%)]</td>
<td>61 (35.7)</td>
<td>66 (32)</td>
<td>105 (30.7)</td>
<td>115 (28.2)</td>
</tr>
<tr>
<td>Shooting/stabbing [n (%)]</td>
<td>9 (5.3)</td>
<td>21 (10.2)</td>
<td>22 (6.4)</td>
<td>19 (4.7)</td>
</tr>
<tr>
<td>Other [n (%)]</td>
<td>20 (11.7)</td>
<td>22 (10.7)</td>
<td>32 (9.4)</td>
<td>36 (8.8)</td>
</tr>
<tr>
<td>Trauma type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blunt [n (%)]</td>
<td>160 (93.6)</td>
<td>182 (88.3)</td>
<td>315 (92.1)</td>
<td>384 (94.1)</td>
</tr>
<tr>
<td>Penetrating [n (%)]</td>
<td>11 (6.4)</td>
<td>24 (11.7)</td>
<td>27 (7.9)</td>
<td>24 (5.9)</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median [n (IQR)]</td>
<td>9 (9-17)</td>
<td>9 (9-16)</td>
<td>9 (9-16)</td>
<td>9 (9-16)</td>
</tr>
<tr>
<td>1-8 [n (%)]</td>
<td>18 (10.5)</td>
<td>40 (19.4)</td>
<td>44 (12.9)</td>
<td>44 (10.8)</td>
</tr>
<tr>
<td>9-14 [n (%)]</td>
<td>83 (48.5)</td>
<td>112 (54.4)</td>
<td>201 (58.8)</td>
<td>244 (59.8)</td>
</tr>
<tr>
<td>≥15 [n (%)]</td>
<td>70 (41)</td>
<td>54 (26.2)</td>
<td>97 (28.4)</td>
<td>120 (29.4)</td>
</tr>
</tbody>
</table>

Whilst the proportion of children seen by a consultant in the emergency department when they initially presented increased over time from 33.9% (95% CI 26.9-41.5) in 2008/9 vs 41.9% (95% CI 41.1-51.9) in 2011/12 this change was not statistically significant. Even though the proportion of children requiring CT fell from 48.1% (95% CI 41.1-55.1) in 2009/10 to 40.9% (95% CI 35.7-46.4) in 2011/12 this change was not statistically significant as was the time to CT scan, even though this, again, fell year on year (1.2 hours 2008/9 vs 0.9 hours 2011/12). Whilst there was no obvious pattern to the number requiring surgery over time, the median time to surgery increased over the period from 15.9 hours in 2009/10 to 19.7 hours in 2012/13, although this was not statistically significant. Both the median LOS in hospital and ICU fell from eight and two days in 2009/10 to seven and one day in 2012/13 respectively (p = 0.13, 0.56, t-test). Mortality within 30 days fell from 6.4% (95% CI 3.6-11.2) in 2008/9 to 2.9% (95% CI 1.7-5.1) in 2011/12 whilst the proportion developing in-hospital complications remained small (5-7%) and demonstrated no obvious change over time.
Table 16: Transfer, management and outcomes of major trauma paediatric patients in Greater London 2008-2012

<table>
<thead>
<tr>
<th></th>
<th>2008/09</th>
<th>2009/10</th>
<th>2010/11</th>
<th>2011/12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trauma patients (n)</td>
<td>171</td>
<td>206</td>
<td>342</td>
<td>408</td>
</tr>
<tr>
<td>Initial transport to MTC [n (%)]</td>
<td>58 (33.9)</td>
<td>110 (53.4)</td>
<td>126 (36.8)</td>
<td>135 (33.1)</td>
</tr>
<tr>
<td>Secondary transfer to MTC [n (%)]</td>
<td>51 (29.8)</td>
<td>60 (29.1)</td>
<td>60 (17.5)</td>
<td>66 (16.2)</td>
</tr>
<tr>
<td>ISS ≥15 directly admitted to MTC [n (%)]</td>
<td>35 (50)</td>
<td>26 (48.1)</td>
<td>60 (61.9)</td>
<td>79 (65.8)</td>
</tr>
<tr>
<td>ISS ≥15 treated entirely outside MTC [n (%)]</td>
<td>20 (28.6)</td>
<td>15 (27.7)</td>
<td>12 (24.1)</td>
<td>10 (8.3)</td>
</tr>
<tr>
<td>Patients admitted to ICU [n (%)]</td>
<td>53 (31)</td>
<td>40 (19.4)</td>
<td>79 (23.1)</td>
<td>81 (19.9)</td>
</tr>
<tr>
<td>Median LOS on ICU [n of days (IQR)]</td>
<td>2 (1-4)</td>
<td>2 (1-4)</td>
<td>2 (1-4)</td>
<td>1 (1-3)</td>
</tr>
<tr>
<td>Median LOS in hospital [n of days (IQR)]</td>
<td>8 (4-12)</td>
<td>6.5 (4-14)</td>
<td>6.5 (4-14.8)</td>
<td>7 (4-13)</td>
</tr>
<tr>
<td>Presented between 00.00-08.00 [n (%)]</td>
<td>20 (11.7)</td>
<td>21 (10.2)</td>
<td>30 (8.8)</td>
<td>32 (7.8)</td>
</tr>
<tr>
<td>Consultant led trauma call [n (%)]</td>
<td>58 (33.9)</td>
<td>82 (39.8)</td>
<td>159 (46.5)</td>
<td>171 (41.9)</td>
</tr>
<tr>
<td>Number documented to have CT scan [n (%)]</td>
<td>77 (45)</td>
<td>99 (48.1)</td>
<td>140 (40.9)</td>
<td>168 (41.2)</td>
</tr>
<tr>
<td>Median time to CT [hours (IQR)]</td>
<td>1.2 (0.7-3.2)</td>
<td>1.1 (0.7-1.9)</td>
<td>0.9 (0.5-2.2)</td>
<td>0.9 (0.5-2.8)</td>
</tr>
<tr>
<td>Number documented to require surgery [n (%)]</td>
<td>68 (39.8)</td>
<td>96 (46.6)</td>
<td>149 (43.6)</td>
<td>147 (36)</td>
</tr>
<tr>
<td>Median time to surgery in hours [hours (IQR)]</td>
<td>15.9 (3.5-80.3)</td>
<td>20.9 (4.9-64)</td>
<td>16.9 (4.2-63.2)</td>
<td>19.7 (6.7-78.7)</td>
</tr>
<tr>
<td>Developed complications [n (%)]</td>
<td>9 (5.3)</td>
<td>12 (5.8)</td>
<td>24 (7)</td>
<td>22 (5.4)</td>
</tr>
<tr>
<td>Mortality within 30 days [n (%)]</td>
<td>11 (6.4)</td>
<td>7 (3.4)</td>
<td>13 (3.8)</td>
<td>12 (2.9)</td>
</tr>
</tbody>
</table>

Greater London adults

Submissions to TARN increased 302% from 1539 cases in 2008/9 to 6194 in 2011/12 following the introduction of the London trauma system (Table 17). From 2008/9 to 2011/12 the median age increased from 42 to 54.8 years ($p < 0.05$, t-test) and the proportion of men being injured fell from 71.5% (95% CI 19-23.1) in 2008/9 to 63.6% (95% CI 43.4-45.9) in 2011/12. The most common mechanism of injury was vehicular incidents in the pre-implementation phase accounting for 37.8% (95% CI 35.3-40.2) of injuries in 2008/9 although this fell over time to 23.6% (95% CI 22.6-24.7) in 2011/12. As injuries caused by vehicles fell over time, the proportion of falls < 2 metres increased from 21% (95% CI 19-23.1) in 2008/9 to 44.6% (95% CI 43.4-45.9) in 2011/12. ISS fell during the study period with a median ISS of 11 in 2008/9 to 9 in 2011/12. The proportion of patients with ISS ≥15 also fell consistently over the four years from 42.2% (95% CI 39.8-44.7) to 36.8% (95% CI 35.6-38).
Table 17: Profile of adult major trauma patients in Greater London 2008-2012

<table>
<thead>
<tr>
<th>Patient characteristic</th>
<th>2008/09</th>
<th>2009/10</th>
<th>2010/11</th>
<th>2011/12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trauma patients (n)</td>
<td>1539</td>
<td>2695</td>
<td>4926</td>
<td>6194</td>
</tr>
<tr>
<td>Median age [years (IQR)]</td>
<td>42 (27.4-61.1)</td>
<td>46.1 (28.7-64.7)</td>
<td>51.3 (31.7-71.7)</td>
<td>54.8 (34.9-76.4)</td>
</tr>
<tr>
<td>Male [n (%)]</td>
<td>1100 (71.5)</td>
<td>1804 (66.9)</td>
<td>3209 (65.1)</td>
<td>3942 (63.6)</td>
</tr>
<tr>
<td>Mechanism of injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall &lt;2m [n (%)]</td>
<td>323 (21)</td>
<td>791 (29.4)</td>
<td>1938 (39.3)</td>
<td>2764 (44.6)</td>
</tr>
<tr>
<td>Fall &gt;2m [n (%)]</td>
<td>302 (19.6)</td>
<td>518 (19.2)</td>
<td>859 (17.4)</td>
<td>961 (15.5)</td>
</tr>
<tr>
<td>Blunt assault [n (%)]</td>
<td>91 (5.9)</td>
<td>174 (6.5)</td>
<td>362 (7.3)</td>
<td>439 (7.1)</td>
</tr>
<tr>
<td>Vehicle incident/collision [n (%)]</td>
<td>581 (37.8)</td>
<td>827 (30.7)</td>
<td>1215 (24.7)</td>
<td>1463 (23.6)</td>
</tr>
<tr>
<td>Shooting/stabbing [n (%)]</td>
<td>138 (9)</td>
<td>259 (9.6)</td>
<td>364 (7.4)</td>
<td>354 (5.7)</td>
</tr>
<tr>
<td>Other [n (%)]</td>
<td>104 (6.8)</td>
<td>126 (4.7)</td>
<td>188 (3.8)</td>
<td>213 (3.4)</td>
</tr>
<tr>
<td>Trauma type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blunt [n (%)]</td>
<td>1387 (90.1)</td>
<td>2407 (89.3)</td>
<td>4501 (91.4)</td>
<td>5647 (90.8)</td>
</tr>
<tr>
<td>Penetrating [n (%)]</td>
<td>152 (9.9)</td>
<td>288 (10.7)</td>
<td>425 (8.6)</td>
<td>547 (9.2)</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median [n (IQR)]</td>
<td>11 (9-22)</td>
<td>10 (9-21)</td>
<td>10 (9-19)</td>
<td>9 (9-17)</td>
</tr>
<tr>
<td>1-8 [n (%)]</td>
<td>233 (15.2)</td>
<td>492 (18.3)</td>
<td>992 (20.1)</td>
<td>1269 (20.5)</td>
</tr>
<tr>
<td>9-14 [n (%)]</td>
<td>656 (42.6)</td>
<td>1091 (40.5)</td>
<td>1995 (40.5)</td>
<td>2647 (42.7)</td>
</tr>
<tr>
<td>≥15 [n (%)]</td>
<td>650 (42.2)</td>
<td>1112 (41.3)</td>
<td>1939 (39.4)</td>
<td>2278 (36.8)</td>
</tr>
</tbody>
</table>

The proportion of patients transported directly to a MTC increased over the study period from 31.7% (95% CI 27.4-32) in 2008/9 to 57.2% (95% CI 55.1-57.6) in 2011/12 and secondary transfers fell from 28.7% (95% CI 26.5-31.1) to 16.6% (95% CI 15.7-17.5) over the same time frame (Table 18). A similar trend could also be demonstrated in the sub-group of patients with ISS ≥15 where direct transfers to an MTC increased year on year from 36% (95% CI 32.3-39.8) in 2008/9 to 73% (95% CI 71.1-74.8) in 2011/12 and the proportion of those seriously injured and treated entirely outside of a MTC also fell from 36.2% (95% CI 33.2-39.1) in 2009/10 to 17.6% (95% CI 16-19.2) over the same time-frame. Whilst the proportion of patients admitted to ICU fell from 30.8% (95% CI 28.5-33.2) in 2008/9 to 19.5% (95% CI 18.5-20.5) in 2011/12, the median LOS and LOS on ICU remained static at nine and three days respectively.

Between 2008/9 and 2011/12, the proportion of patients seeing a consultant on arrival increased from 33.2% (95% CI 30.9-35.6) to 40.7% (95% CI 39.4-41.9). The proportion of patients requiring a CT remained stable at around 60% with the median time to CT around 1.4 hours for each year. The proportion requiring surgery fell from 48.5% (95% CI 45.1-50.2) in
2009/10 to 35.6% (95% CI 34.4-36.8) in 2011/12. However, the time to surgery increased from 15 hours in 2008/9 to 20.5 hours in 2011/12 (p<0.05, t-test). Whilst the proportion of patients who developed complications increased from 6.3% (95% CI 5.1-7.6) in 2008/9 to 11.4% (95% CI 10.2-12.7) the following year, there was no further statistically significant change over time.

Even though 30-day mortality fell in the two years post trauma system implementation compared to the two years before, the observed changes were not statistically significant.

**Table 18:** Transfer, management and outcomes of major trauma adult patients in Greater London 2008-2012

<table>
<thead>
<tr>
<th></th>
<th>2008/09</th>
<th>2009/10</th>
<th>2010/11</th>
<th>2011/12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trauma patients (n)</td>
<td>1539</td>
<td>2695</td>
<td>4926</td>
<td>6194</td>
</tr>
<tr>
<td>Initial transport to MTC [n (%)]</td>
<td>456 (31.7)</td>
<td>806 (33.6)</td>
<td>1939 (39.4)</td>
<td>3492 (57.2)</td>
</tr>
<tr>
<td>Secondary transfer to MTC [n (%)]</td>
<td>442 (28.7)</td>
<td>546 (20.3)</td>
<td>813 (16.5)</td>
<td>1027 (16.6)</td>
</tr>
<tr>
<td>ISS ≥15 directly admitted to MTC [n (%)]</td>
<td>234 (36)</td>
<td>601 (54)</td>
<td>811 (71.2)</td>
<td>1662 (73)</td>
</tr>
<tr>
<td>ISS ≥15 treated entirely outside MTC [n (%)]</td>
<td>226 (34.8)</td>
<td>402 (36.2)</td>
<td>279 (24.5)</td>
<td>400 (17.6)</td>
</tr>
<tr>
<td>Patients admitted to ICU [n (%)]</td>
<td>474 (30.8)</td>
<td>806 (29.9)</td>
<td>1175 (23.9)</td>
<td>1208 (19.5)</td>
</tr>
<tr>
<td>Median LOS on ICU [days (IQR)]</td>
<td>3 (1-6)</td>
<td>3 (2-8)</td>
<td>4 (1-9)</td>
<td>3 (1-8)</td>
</tr>
<tr>
<td>Median LOS in hospital [days (IQR)]</td>
<td>9 (5-19)</td>
<td>9 (5-19)</td>
<td>9 (5-18)</td>
<td>9 (5-17)</td>
</tr>
<tr>
<td>Presented between 00.00-08.00 [n (%)]</td>
<td>323 (21)</td>
<td>546 (20.3)</td>
<td>954 (19.4)</td>
<td>1096 (17.7)</td>
</tr>
<tr>
<td>Consultant led trauma call [n (%)]</td>
<td>511 (33.2)</td>
<td>917 (34)</td>
<td>1866 (37.9)</td>
<td>2519 (40.7)</td>
</tr>
<tr>
<td>Number documented to have CT scan [n (%)]</td>
<td>935 (60.8)</td>
<td>1636 (60.7)</td>
<td>2847 (57.8)</td>
<td>3661 (59.1)</td>
</tr>
<tr>
<td>Median time to CT [hours (IQR)]</td>
<td>1.4 (0.7-3.2)</td>
<td>1.5 (0.7-4)</td>
<td>1.5 (0.7-4.2)</td>
<td>1.4 (0.6-4.5)</td>
</tr>
<tr>
<td>Number documented to require surgery [n (%)]</td>
<td>733 (47.6)</td>
<td>1307 (48.5)</td>
<td>1932 (39.2)</td>
<td>2204 (35.6)</td>
</tr>
<tr>
<td>Median time to surgery [hours (IQR)]</td>
<td>15 (1.3-42.9)</td>
<td>17.6 (4.8-45.8)</td>
<td>19.3 (5.5-45.8)</td>
<td>20.5 (7.6-47.6)</td>
</tr>
<tr>
<td>Developed complications [n (%)]</td>
<td>97 (6.3)</td>
<td>307 (11.4)</td>
<td>675 (13.7)</td>
<td>800 (12.9)</td>
</tr>
<tr>
<td>Mortality within 30 days [n (%)]</td>
<td>121 (7.9)</td>
<td>229 (8.5)</td>
<td>339 (6.9)</td>
<td>435 (7)</td>
</tr>
</tbody>
</table>

**Survival for adults and children**

The excess rate of survival for each year adjusted for key predictors of mortality (e.g. age, ISS, gender and Glasgow Coma Score) is shown in Figure 6. This Ws statistic increased from -0.45 (-1.38 to 0.48) in 2008/9 to 0.52 (0.05-0.99) in 2011/12 and has continued on an upward trend since. This increase over time indicates that since 2010/11, more patients survived beyond that expected (i.e. 0.52 more lives were saved per 100 patients in 2011/12).
Figure 24: Standardised rate of survival (Ws) per year in Greater London Trauma Network (Adults and children)

Greater Manchester children

The total number of cases submitted to TARN of serious injury in children and treated in Greater Manchester hospitals increased 31.2% during the study period from 170 in 2010/11 to 223 in 2013/14 (Table 19). As in London, most injuries were sustained by young males (median age 5.5 – 7.4 years) and were caused by falls from low height (<2 metres) or vehicle collisions. The proportion injured in falls from low height (<2 metres) increased over time from 34.1% (95% CI 27-41.8) in 2010/11 to 43% (95% CI 36.5-49.8) in 2013/14. However, the proportion of penetrating injuries was consistently low (1.6-3.1%). Most injuries were of moderate injury severity as defined by the ISS with the median ISS being nine each year and between 30-38% of patients suffering a high injury severity (ISS ≥15). There was no statistically significant change over time in either mechanism of injury or ISS.
Table 19: Profile of paediatric major trauma patients in Greater Manchester 2010-2014

<table>
<thead>
<tr>
<th>Patient characteristic</th>
<th>2010/11</th>
<th>2011/12</th>
<th>2012/13</th>
<th>2013/14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trauma patients (n)</td>
<td>170</td>
<td>184</td>
<td>203</td>
<td>223</td>
</tr>
<tr>
<td>Median age [years (IQR)]</td>
<td>7.4 (2.6-12.3)</td>
<td>5.5 (1.8-12)</td>
<td>5.5 (1.8-11.1)</td>
<td>6.4 (2.1-12.3)</td>
</tr>
<tr>
<td>Male [n (%)]</td>
<td>126 (74.1)</td>
<td>150 (70.7)</td>
<td>135 (66.5)</td>
<td>158 (70.9)</td>
</tr>
<tr>
<td>Mechanism of injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall &lt;2m [n (%)]</td>
<td>58 (34.1)</td>
<td>77 (41.8)</td>
<td>86 (42.4)</td>
<td>96 (43)</td>
</tr>
<tr>
<td>Fall &gt;2m [n (%)]</td>
<td>32 (18.8)</td>
<td>22 (12)</td>
<td>24 (11.8)</td>
<td>32 (14.3)</td>
</tr>
<tr>
<td>Blunt assault [n (%)]</td>
<td>13 (7.6)</td>
<td>10 (5.4)</td>
<td>11 (5.4)</td>
<td>8 (3.6)</td>
</tr>
<tr>
<td>Vehicle incident/collision [n (%)]</td>
<td>37 (21.8)</td>
<td>47 (25.5)</td>
<td>52 (25.6)</td>
<td>54 (23.8)</td>
</tr>
<tr>
<td>Shooting/stabbing [n (%)]</td>
<td>2 (1.2)</td>
<td>1 (0.5)</td>
<td>1 (0.5)</td>
<td>4 (1.8)</td>
</tr>
<tr>
<td>Other [n (%)]</td>
<td>28 (16.5)</td>
<td>27 (14.7)</td>
<td>29 (14.3)</td>
<td>29 (13)</td>
</tr>
<tr>
<td>Trauma type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blunt [n (%)]</td>
<td>166 (97.6)</td>
<td>181 (98.4)</td>
<td>200 (98.5)</td>
<td>216 (96.9)</td>
</tr>
<tr>
<td>Penetrating [n (%)]</td>
<td>6 (2.4)</td>
<td>3 (1.6)</td>
<td>3 (1.5)</td>
<td>7 (3.1)</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median [n (IQR)]</td>
<td>9 (9-16)</td>
<td>9 (9-17)</td>
<td>9 (9-20)</td>
<td>9 (9-16)</td>
</tr>
<tr>
<td>1-8 [n (%)]</td>
<td>17 (10)</td>
<td>23 (12.5)</td>
<td>26 (12.8)</td>
<td>31 (13.9)</td>
</tr>
<tr>
<td>9-14 [n (%)]</td>
<td>96 (56.5)</td>
<td>97 (52.7)</td>
<td>101 (49.8)</td>
<td>126 (56.5)</td>
</tr>
<tr>
<td>≥15 [n (%)]</td>
<td>57 (33.5)</td>
<td>64 (34.8)</td>
<td>76 (37.4)</td>
<td>66 (29.6)</td>
</tr>
</tbody>
</table>

Following the introduction of the trauma network, the proportion of injured children transported directly to an MTC increased from 29.4% (95% CI 22.7-36.9) in 2010/11 to 49.3% (95% CI 42.6-56.1) in 2013/14, whilst the number of patients requiring secondary transfer fell from 54.7% (95% CI 46.9-62.3) to 40.8% (95% CI 34.3-47.6) over the same time-frame (Table 20). In a separate analysis of those with ISS ≥15, the proportion directly taken to an MTC increased from 10.5% (95% CI 4-21.5) in 2010/11 to 43.9% (95% CI 31.7-56.7) in 2013/14 with the proportion having all of their care provided outside an MTC falling from 8.8% in 2010/11 (95% CI 2.9-19.3) to 1.5% (95% CI 0-8.2) in 2013/14.

The overall length of stay in hospital fell from nine days in 2011/12 to six days in 2013/14 (p=<0.05, t-test). Whilst the proportion of trauma calls being led by a consultant increased dramatically from 18% (95% CI 12.7-24.9) in 2010/11 to 62% (95% CI 55.6-68.7) in 2013/14 and the time to CT fell from 4.7 hours to 0.9 (p=<0.05, t-test), the median time to surgery
increased (14.7 hrs 2010/11 vs 18.9 hrs 2013/14) (p=0.13, t-test). There was an upward trend over time in the proportion of patients requiring a CT from 34.8% (95% CI 27.9-42.1) in 2011/12 to 41.7% (95% CI 36-50) in 2013/14 but this was not statistically significant. The number developing complications following admission to hospital fell from 8.2% in 2011/12 to 0.4% in 2013/14 although the number of children who died increased from two (0.6% (95% CI 0.1-2)) in the first two-year period to ten (2.3% (95% CI 1.1-4.3)) in the second two years.

Table 20: Transfer, management and outcomes of paediatric major trauma patients in Greater Manchester 2010-2014

<table>
<thead>
<tr>
<th>Trauma patients (n)</th>
<th>2010/11</th>
<th>2011/12</th>
<th>2012/13</th>
<th>2013/14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial transport to MTC [n (%)]</td>
<td>50 (29.4)</td>
<td>61 (33.2)</td>
<td>90 (44.3)</td>
<td>110 (49.3)</td>
</tr>
<tr>
<td>ISS ≥15 directly admitted to MTC [n (%)]</td>
<td>6 (12)</td>
<td>7 (10.6)</td>
<td>16 (21.1)</td>
<td>29 (43.9)</td>
</tr>
<tr>
<td>ISS ≥15 treated entirely outside MTC [n (%)]</td>
<td>5 (8.8)</td>
<td>5 (7.8)</td>
<td>2 (2.6)</td>
<td>1 (1.5)</td>
</tr>
<tr>
<td>Secondary transfer to MTC [n (%)]</td>
<td>93 (54.7)</td>
<td>88 (47.8)</td>
<td>106 (52.2)</td>
<td>91 (40.8)</td>
</tr>
<tr>
<td>Patients admitted to ICU [n (%)]</td>
<td>40 (23.5)</td>
<td>41 (22.3)</td>
<td>58 (28.6)</td>
<td>48 (21.5)</td>
</tr>
<tr>
<td>Median LOS on ICU [days (IQR)]</td>
<td>3 (1-6)</td>
<td>2 (2-5)</td>
<td>3 (1-6)</td>
<td>3 (2-4)</td>
</tr>
<tr>
<td>Median LOS in hospital [days (IQR)]</td>
<td>8 (5-16)</td>
<td>9 (5-17)</td>
<td>7 (4-15)</td>
<td>6 (4-14)</td>
</tr>
<tr>
<td>Presented between 00.00-08.00 [n (%)]</td>
<td>22 (12.9)</td>
<td>12 (6.5)</td>
<td>20 (9.9)</td>
<td>22 (9.9)</td>
</tr>
<tr>
<td>Consultant led trauma call [n (%)]</td>
<td>31 (18.2)</td>
<td>54 (29.3)</td>
<td>95 (46.8)</td>
<td>139 (62.3)</td>
</tr>
<tr>
<td>Number documented to have CT scan [n (%)]</td>
<td>61 (35.9)</td>
<td>64 (34.8)</td>
<td>87 (42.9)</td>
<td>93 (41.7)</td>
</tr>
<tr>
<td>Median time to CT [hours (IQR)]</td>
<td>4.7 (1.2-20.5)</td>
<td>3.2 (1.6-18.8)</td>
<td>1.8 (0.7-4.5)</td>
<td>0.9 (0.4-4.3)</td>
</tr>
<tr>
<td>Median time to surgery [hours (IQR)]</td>
<td>14.7 (3.5-57.1)</td>
<td>17 (5.8-44.9)</td>
<td>17.9 (4.3-99)</td>
<td>18.9 (5.3-68.7)</td>
</tr>
<tr>
<td>Developed complications [n (%)]</td>
<td>13 (7.6)</td>
<td>15 (8.2)</td>
<td>4 (2)</td>
<td>1 (0.4)</td>
</tr>
<tr>
<td>Mortality within 30 days [n (%)]</td>
<td>0 (0)</td>
<td>2 (1.1)</td>
<td>6 (3)</td>
<td>4 (1.8)</td>
</tr>
</tbody>
</table>

Greater Manchester adults

The number of injured adult patients submitted to TARN from the Greater Manchester emergency departments increased by 48.4% from 2010/11 (1677 cases) to 2013/14 (2496 cases) (Table 21). The majority of those injured were male (between 55.7-59.2% each year) with the median age increasing over the study period (56.3yrs 2010/11 vs 62.1yrs 2013/14 (p=<0.05, t-test). Each year most injuries were secondary to falls and despite an increase in falls from less than two metres from 56.8% (95% CI 54.5-58.9) in 2011/12 to 63.2% (95% CI 61.3-65.1) in 2012/13, there was no other statistically significant change in MOI between the
years. Whilst the median ISS was 9 throughout the study, the proportion seriously injured with an ISS $\geq 15$ increased from 26.4% (95% CI 24.4-28.4) in 2011/12 to 33.8% (95% CI 32-35.7) in 2013/14, following the introduction of the trauma system.

Table 21: Characteristics of adult major trauma patients in Greater Manchester 2010-2014

<table>
<thead>
<tr>
<th>Patient characteristic</th>
<th>2010/11</th>
<th>2011/12</th>
<th>2012/13</th>
<th>2013/14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trauma patients (n)</td>
<td>1677</td>
<td>1975</td>
<td>2561</td>
<td>2496</td>
</tr>
<tr>
<td>Median age [years (IQR)]</td>
<td>56.3 (37.1-74.7)</td>
<td>57.9 (40.9-77.1)</td>
<td>61.1 (43.1-79.4)</td>
<td>62.1 (43.8-80.4)</td>
</tr>
<tr>
<td>Male [n (%)]</td>
<td>993 (59.2)</td>
<td>1152 (58.3)</td>
<td>1426 (55.7)</td>
<td>1450 (58.1)</td>
</tr>
<tr>
<td>Mechanism of injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall &lt;2m [n (%)]</td>
<td>926 (55.2)</td>
<td>1121 (56.8)</td>
<td>1618 (63.2)</td>
<td>1482 (59.4)</td>
</tr>
<tr>
<td>Fall &gt;2m [n (%)]</td>
<td>231 (13.8)</td>
<td>269 (13.6)</td>
<td>297 (11.6)</td>
<td>348 (13.9)</td>
</tr>
<tr>
<td>Blunt assault [n (%)]</td>
<td>148 (8.8)</td>
<td>155 (7.8)</td>
<td>179 (7)</td>
<td>176 (7.1)</td>
</tr>
<tr>
<td>Vehicle incident/collision [n (%)]</td>
<td>234 (14)</td>
<td>298 (15.1)</td>
<td>334 (13)</td>
<td>386 (15.5)</td>
</tr>
<tr>
<td>Shooting/stabbing [n (%)]</td>
<td>36 (2.2)</td>
<td>39 (2)</td>
<td>56 (2.2)</td>
<td>43 (1.7)</td>
</tr>
<tr>
<td>Other [n (%)]</td>
<td>102 (6.1)</td>
<td>93 (4.7)</td>
<td>77 (3)</td>
<td>61 (2.4)</td>
</tr>
<tr>
<td>Trauma type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blunt [n (%)]</td>
<td>1626 (96.9)</td>
<td>1925 (97.5)</td>
<td>2487 (97.1)</td>
<td>2433 (97.5)</td>
</tr>
<tr>
<td>Penetrating [n (%)]</td>
<td>52 (3.1)</td>
<td>50 (2.5)</td>
<td>74 (2.9)</td>
<td>63 (2.5)</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median [n (IQR)]</td>
<td>9 (8-16)</td>
<td>9 (8-16)</td>
<td>9 (8-16)</td>
<td>9 (9-17)</td>
</tr>
<tr>
<td>1-8 [n (%)]</td>
<td>452 (26.9)</td>
<td>540 (27.3)</td>
<td>655 (25.6)</td>
<td>584 (23.4)</td>
</tr>
<tr>
<td>9-14 [n (%)]</td>
<td>762 (45.4)</td>
<td>914 (46.3)</td>
<td>1170 (45.7)</td>
<td>1068 (42.8)</td>
</tr>
<tr>
<td>$\geq$15 [n (%)]</td>
<td>464 (27.7)</td>
<td>521 (26.4)</td>
<td>736 (28.7)</td>
<td>844 (33.8)</td>
</tr>
</tbody>
</table>

As was seen with injured children in Greater Manchester, the proportion taken directly to a MTC increased from 28.8% (95% CI 26.8-30.9) in 2011/12 to 51.8% (95% CI 49.9-53.8) in 2013/14. The proportion of secondary transfers fell initially before increasing from 20.5% (95% CI 19.2-22.1) in 2012/13 to 24% (22.3-25.7) in 2013/14 (Table 22). In those most seriously injured (ISS $\geq 15$), the trend for increased MTC care was duplicated with the proportion taken directly to a MTC increasing from 18.1% (95% CI 14.7-21.9) in 2010/11 to 48.6% (95% CI 45.2-52) in 2013/14. The proportion treated entirely outside an MTC also fell from 40.3% (95% CI 35.8-44.9) in 2010/11 to 14.9% (95% CI 12.6-17.5) in 2013/14.
Whilst fewer patients were admitted to ICU in 2010/11 (10.1% (95% CI 8.7-11.7)) vs 2013/14 (15.8% (95% CI 14.4-17.3)) there was no statistically significant change in ICU or hospital length of stay (three and ten days respectively), or in the proportion of patients who presented out of hours.

Table 22: Transfer, management and outcomes of adult major trauma patients in Greater Manchester 2010-2014

<table>
<thead>
<tr>
<th></th>
<th>2010/11</th>
<th>2011/12</th>
<th>2012/13</th>
<th>2013/14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trauma patients (n)</td>
<td>1677</td>
<td>1975</td>
<td>2561</td>
<td>2496</td>
</tr>
<tr>
<td>Initial transport to MTC [n (%)]</td>
<td>516 (30.8)</td>
<td>569 (28.8)</td>
<td>1103 (43.1)</td>
<td>1294 (51.8)</td>
</tr>
<tr>
<td>Secondary transfer to MTC [n (%)]</td>
<td>398 (23.7)</td>
<td>399 (20.2)</td>
<td>525 (20.5)</td>
<td>598 (24)</td>
</tr>
<tr>
<td>ISS ≥15 directly admitted to MTC [n (%)]</td>
<td>84 (18.1)</td>
<td>103 (19.8)</td>
<td>280 (38.3)</td>
<td>410 (48.6)</td>
</tr>
<tr>
<td>ISS ≥15 treated entirely outside MTC [n (%)]</td>
<td>187 (40.3)</td>
<td>206 (39.5)</td>
<td>149 (20.2)</td>
<td>126 (14.9)</td>
</tr>
<tr>
<td>Patients admitted to ICU [n (%)]</td>
<td>170 (10.1)</td>
<td>289 (14.6)</td>
<td>346 (13.5)</td>
<td>395 (15.8)</td>
</tr>
<tr>
<td>Median LOS on ICU [days (IQR)]</td>
<td>3 (2-7)</td>
<td>4 (2-8)</td>
<td>3 (1-8)</td>
<td>3 (1-7)</td>
</tr>
<tr>
<td>Median LOS in hospital [days (IQR)]</td>
<td>10 (5-18)</td>
<td>9 (5-20)</td>
<td>10 (5-20)</td>
<td>10 (5-19.3)</td>
</tr>
<tr>
<td>Presented between 00.00-08.00 [n (%)]</td>
<td>313 (18.7)</td>
<td>371 (18.8)</td>
<td>444 (17.3)</td>
<td>439 (17.6)</td>
</tr>
<tr>
<td>Consultant led trauma call [n (%)]</td>
<td>317 (18.9)</td>
<td>524 (26.5)</td>
<td>971 (37.9)</td>
<td>1153 (46.2)</td>
</tr>
<tr>
<td>Number documented to have CT scan [n (%)]</td>
<td>733 (43.7)</td>
<td>973 (49.3)</td>
<td>1450 (56.6)</td>
<td>1486 (59.5)</td>
</tr>
<tr>
<td>Median time to CT [hours (IQR)]</td>
<td>3.4 (1.6-25.1)</td>
<td>3.5 (1.6-23.4)</td>
<td>2.6 (1-16.7)</td>
<td>1.9 (0.7-9.8)</td>
</tr>
<tr>
<td>Number documented to require surgery [n (%)]</td>
<td>678 (40.4)</td>
<td>838 (42.4)</td>
<td>996 (38.9)</td>
<td>914 (36.6)</td>
</tr>
<tr>
<td>Median time to surgery [hours (IQR)]</td>
<td>22.9 (11.7-56.6)</td>
<td>25.9 (13-63.6)</td>
<td>23.6 (13.9-57)</td>
<td>23.8 (13.8-53.9)</td>
</tr>
<tr>
<td>Developed complications [n (%)]</td>
<td>112 (6.7)</td>
<td>143 (7.2)</td>
<td>141 (5.5)</td>
<td>154 (6.2)</td>
</tr>
<tr>
<td>Mortality within 30 days [n (%)]</td>
<td>117 (7)</td>
<td>137 (6.9)</td>
<td>184 (7.2)</td>
<td>167 (6.7)</td>
</tr>
</tbody>
</table>

In terms of process measures, a greater proportion of patients were received by a consultant on arrival to hospital as each year passed, increasing from 18.9% (95% CI 17.1-20.9) in 2010/11 to 46.2% (95% CI 44.2-48.2) in 2013/14. The proportion requiring a CT scan increased from 43.7% (95% CI 41.3-46.1) in 2010/11 to 59.5% in 2013/14 (95% CI 57.6-61.5) and the median time to scan fell from 3.4 hours in 2010/11 to 1.9 hours in 2013/14 (p=<0.05, t-test). Whilst the proportion of patients requiring surgery fell slightly from 2012/13 this change was not statistically significant as was the case with the median time to surgery. Overall, the complication rate and 30-day mortality remained relatively static over the study period.
Survival for adults and children

As shown in Figure 25, the standardised rate of survival (Ws statistic) improved from -1.13 (-2.14 to -0.12) in 2010/11 to 0.67 (-0.02 to 1.36) in 2013/14 (0.67 extra lives/100 saved when they would not be expected to survive). Despite an upward trend in survival in the two years following trauma system implementation in Greater Manchester, as the confidence intervals include the null value, no statistically significant difference can be demonstrated between the groups.

![Figure 25: Standardised rate of survival per year (Ws) in Greater Manchester Trauma Network (Adults and children)](image)

Synopsis

Throughout the study period there has been a substantial increase in the number of submissions to TARN for both adults and children in both Greater London and Greater Manchester. Men were more frequently represented than women and most injuries were secondary to falls, a trend that seems to be increasing. Whilst minor stochastic variation can be seen in most of the variables studied, there are a number of trends that have been observed...
in the two years following the implementation of regional trauma systems that are both clinically and statistically significant:

- The proportion of injuries caused by falls is increasing
- The median age of those injured is increasing
- The proportion of injured patients taken directly to a MTC has increased
- The proportion of patients requiring a secondary transfer to another hospital to receive definitive care fell
- The proportion of seriously injured patients (ISS ≥ 15) treated entirely outside of a MTC has fallen
- The proportion of patients seen by a consultant on their arrival to hospital has increased
- In Greater Manchester, the time to CT has fallen dramatically
- The standardised rate of survival has increased (although not statistically significant in Greater Manchester), demonstrating that more patients are surviving than would be expected to survive

In the following chapter, the results from the qualitative study are presented. These observations will subsequently be interpreted and discussed in further detail along with the quantitative results presented here.

**Box 2: Summary of key quantitative study findings**

<table>
<thead>
<tr>
<th>What is already known on this topic</th>
<th>What this study adds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trauma causes a significant number of deaths, increasingly affecting the elderly</td>
<td>Uses a novel dataset to add to the body of evidence that trauma patients are becoming older</td>
</tr>
<tr>
<td>Falls are overtaking vehicle collisions as the primary cause of trauma</td>
<td>Identifies a considerable burden of trauma death outside of hospital</td>
</tr>
<tr>
<td>There are many studies, mainly of poor methodological quality, showing a survival advantage when trauma systems are introduced to a population</td>
<td>Standardised rate of survival shows upward trend over time in regions that have implemented a trauma system compared to those that have not</td>
</tr>
<tr>
<td></td>
<td>Process measures such as time to CT scan are reduced following system implementation</td>
</tr>
<tr>
<td></td>
<td>A greater proportion of seriously injured patients are now being treated in major trauma centres</td>
</tr>
</tbody>
</table>
Chapter 5: Qualitative results
Background

In the previous chapter, I presented the quantitative results. This data provided information on the burden of trauma in Greater London, Greater Manchester and South Wales and provided evidence that since the introduction of regional trauma systems in Greater London and Greater Manchester, overall mortality from trauma has fallen. The data also suggested that a number of process measures, such as time to CT scan, also fell following the introduction of the systems. Whilst the quantitative data can be used to answer some of the objectives of the study, they cannot be used to answer all.

In this chapter I present the qualitative results of this mixed-methods study. As outlined in chapter three, I used semi-structured interviews to explore the views of NHS clinical staff who provide or provided trauma care to patients in Greater London or Greater Manchester before, during and after trauma system implementation in each region. The purpose of carrying out such a study was to provide a more complete understanding of the impact of trauma systems on patient care and patient outcomes and to explore the drivers and barriers to successful implementation and operation. In particular, the qualitative study will help to address two of the five study objectives:

- To explore the views of NHS emergency department staff on the reorganisation of regional trauma care, any perceived risks or benefits of such change and, to explore the importance of individual processes with a trauma system
- To provide recommendations to improve the operational effectiveness of current trauma systems and in the implementation of any future system

Following the interviews, framework analysis was used to manage, interrogate and interpret the data and to ultimately develop interpretive concepts (themes) to describe and explain the data. Seven such themes were identified and these are described in detail overleaf.
In the following chapter, both the qualitative and quantitative results will then be integrated to help provide a multi-dimensional understanding of the research question and areas of agreement and disagreement explored in further detail.

**Study objectives**

The study was conducted from July 2015 to January 2016. I invited twenty-one staff to participate and all, except one, agreed. Twenty semi-structured interviews were completed with nine nursing and eleven medical staff from both Greater London and Greater Manchester and who worked in multiple NHS Emergency Departments (EDs) that provided a range of trauma care. The numbers and role of participants interviewed by region and centre type is presented in Table 23. Study regions were randomly assigned a letter to maintain anonymity.

Table 23. Number of staff interviewed in each region by professional role

<table>
<thead>
<tr>
<th>Professional Role</th>
<th>Region A</th>
<th>Region B</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consultant - MTC</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Consultant - TU</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Consultant - NTRH</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Senior nurse - MTC</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Senior nurse - TU</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Senior nurse - NTRH</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8</strong></td>
<td><strong>12</strong></td>
<td><strong>20</strong></td>
</tr>
</tbody>
</table>

Each interview was conducted by MD and took an average of 58 minutes, ranging from 42 to 70 minutes. All participants had worked in an ED between four and thirty-five years, with an average of sixteen years. All had experienced the process of trauma system implementation and the provision of trauma care before and after. Interviewer and participant characteristics are outlined in Table 24.
Table 24. Interviewer and interview characteristics

<table>
<thead>
<tr>
<th>Interviewer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which author conducted the interviews</td>
</tr>
<tr>
<td>Qualifications</td>
</tr>
<tr>
<td>Occupation at time of interviews</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Training</td>
</tr>
<tr>
<td>Interviewer already known to participants?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting</td>
</tr>
<tr>
<td>Who was present</td>
</tr>
<tr>
<td>Duration</td>
</tr>
<tr>
<td>Audio recording</td>
</tr>
<tr>
<td>Consent</td>
</tr>
<tr>
<td>Confidentiality</td>
</tr>
<tr>
<td>Transcription</td>
</tr>
<tr>
<td>Field notes</td>
</tr>
<tr>
<td>Repeat interviews</td>
</tr>
</tbody>
</table>

Findings

Analysis of participants accounts raised seven dominant themes. Whilst individuals worked in differing roles and settings, these themes permeated all of the accounts. Each theme is presented in detail below.

The need for change

There was a unanimous view between all participants in both regions that care of the seriously injured was in desperate need of improvement and was long overdue. Even though staff felt that they managed patients as well as they could, analysis of their accounts suggested three distinct reasons why they felt care was sub-optimal:
• Delay
Participants felt that ‘delay’ was a key feature in creating poor outcomes for the trauma patients of the past. Examples were given of delays being caused by multiple factors, including, waiting for a consultant to attend the department, waiting for a decision to be reached about taking a patient to the operating theatre, waiting for imaging or blood products or indeed waiting for transfer of the patient to another hospital that could provide definitive care.

“The patient was waiting for the doctors instead of the doctors waiting for the patient. And then you would CT the patient and they would have a bleed on the brain that needed a neurosurgery opinion. Then you’re phoning through switchboard. Then you’re waiting for the registrar to get hold of them, and in the meantime the brain injury of the patient is getting worse and worse and you’re trying to mess about with Mannitol and stuff like that, and really, it’s all just delay, delay, delay.” (P5)

Delays in patient care and their throughput from the ED to the ward, intensive care unit, theatre or other hospital were found to be very stressful for both nursing and medical staff.

“I can remember sometimes waiting for the surgeon, the consultant surgeon. You’d have got your patient stabilised and the surgeon on call, which would be the SHO (junior doctor), would be there and then you’d be waiting for your consultant surgeon to arrive. That would delay things. Things like that are very stressful, aren’t they?” (P12)

Many felt that they were then working outside of their comfort zone, understanding that they did not have the skills to deliver the ongoing or definitive care that the patient needed. There was a view that they were the patient’s advocate and whilst trying to expedite people or processes, delays led to frustration and, occasionally, animosity with other staff from outside of the ED.
• **Unreliable care**

Participants appreciated that there was huge variation in how care was delivered, not only between hospitals but even by different consultants and by what time or day the patient presented. Patient care was felt to be time, place and person dependent and this approach was seen to offer unreliable patient care.

“Largely I felt it was fragmented, and now, with a great deal of hindsight, I know it was fragmented. It seemed to be a reasonably ad hoc response dependent on the pre-hospital information that came into the department. Specifically, you couldn’t guarantee what sort of response any given patient might receive, regardless of which hospital they presented at.” (P7)

It was felt that there was a lack of a systematic approach in treating injured patients, certainly up to the 1990’s when courses such as Advanced Trauma Life Support (ATLS) were introduced. The scene was described as being quite chaotic and fragmented with neither nurses nor doctors following treatment pathways or protocols and each wondering what was going to happen next rather than everyone having a plan.

“I mean going back all them years ago each consultant almost had his own way of working. It was like, well which consultant’s on today? So do we do it this way or do it that way? Because each consultant had a particular way. You wouldn’t splint something that way because one consultant did it one way and another. The old, it sounds awful, but the old-fashioned consultants, they were very set in their ways and they liked a thing doing a certain way and that’s how they wanted it.” (P10)

“One of the consultants was excellent in resus, excellent. He wasn’t particularly good otherwise but he did come into his own in the event of a major trauma and he was really good to work with in resus. Then one of the other doctors who worked very differently; he was all over the show and you almost couldn’t follow what he wanted, this, that and the other. He was all of a do. The trouble is when you get somebody like that it sort of
rubs off on the other staff doesn't it, and eventually you all get to a state where you can't really function.” (P10)

Such variation in individual practice was seen to cross boundaries into the EDs of all hospital types, from major teaching hospitals to small district general hospitals. Examples of both poor and excellent care, leadership and outcomes were given at all hospital types but it was universally agreed that excellent care had certainly not been consistent at any.

“I think there was variation in different hospitals I worked in, and it probably demonstrated itself most in terms of how common the consultant body were involved in managing the patients. Now I'm not sure that I necessarily tracked the particular definitions of a hospital. So, for instance, I worked in the district general where consultants were incredibly active in managing all the trauma cases that came in. Certainly, I've worked in teaching hospitals where consultant input was minimal" (P2)

Many of the participants who were consultants admitted that, in the past, trauma cases were left for junior doctors to manage in the ED, particularly at night. Whilst they all agreed that they came in at night if asked, they acknowledged that most of the time they were unaware of the patient until the next morning. Many felt that the role of improved and quicker imaging, such as CT, had made it easier to identify those with serious injuries, compared to the past.

“Even at (name of hospital) when I became a consultant, I thought I was being called for all of the major trauma cases. Well, we now actually know that we didn’t even know which were major trauma cases and which weren’t, so how could they have had that reliable care, so how could the nurses have been certain when to call us?” (P20)

- **Lack of organisational structure**

There was also a view that a lack of teamwork hampered patient care and outcomes. Patients were very much seen to be managed by the ED team with a variable response
from other hospital specialist teams. There was a perception that people were working to their own agendas rather than as a team with the patient’s wellbeing at the centre of decision making.

“We didn't have a set trauma team. So you'd call people as you wanted. Sometimes you'd get both the SHO (junior doctor) and the consultant coming so you'd have two orthopaedics and you might have two surgeons a couple of anaesthetists come in and then you’ve got your A&E doctors and your team - everybody can only see their bit. So the orthopaedics are only in to do the bones, they're not bothered that the patient is going into cardiac arrest. They can't see past the fractures of the limbs and things like that. Each specialty thought their part was the priority.” (P13)

A number of participants also had experience of working in the military in a clinical capacity. As a group, they felt strongly that civilian trauma care in the NHS was “vastly inferior,” with patients dying in the past “that shouldn't have died.” They attributed this to a lack of teamwork and structure. Whilst they viewed their experiences of responding to trauma on the battlefield as “a well-oiled machine”, the NHS response to delivering trauma care resulted in “every man and his dog” turning up to try and help the patient but in reality “there was a lot of running around, lots of noise and very little effective care.” Whilst recognising that the NHS was very different to the military, they felt that it seemed more difficult to implement change. “In the military if someone says do something it gets done. Here it might happen but it would be after a meeting of 20 people.”

Knowledge

Certainly, all those interviewed had an awareness of some of the reports that had been published over the years that recommended improvement to trauma care and the implementation of trauma systems. It seemed to be a relief to many that change had now occurred and that trauma was being given the same priority as other serious illnesses such as stroke and heart attacks, and that there were now benchmarks to measure care against.
“I just think it’s brought trauma up to the same level as other acute emergencies. It’s reset the bar. So, sepsis patients, one hour. Stroke for thrombolysis (‘clot busting’ drug) patients on arrival within thrombolytic window. STEMI (heart attack) patients seen within 20 minutes and transferred to PPCI (unblocking of coronary arteries). Trauma patients. I think the benchmark’s really risen I think.” (P19)

Participants were aware of apparent variation in outcomes across the country and of TARN, its role, and how their department performed when compared to others. This was particularly the case when interviewing staff from Greater Manchester, the home of TARN. Many participants expressed pride that the TARN data from their hospital showed that it was performing well against other hospitals, almost in a competitive fashion. This was particularly found in the MTCs where staff compared their data against the other MTCs in the same city.

Despite all participants being based in the ED, they seemed to have an understanding about the wider patient journey and where problems could occur, from the pre-hospital phase right through to care on the wards and rehabilitation.

“Trauma has a ripple effect. The trauma and the injury doesn’t just happen at the scene. It will continue to happen potentially for days. It’s like throwing a rock into a pond, that ripple will go on and on and on, and if you’re not careful things will catch you out.” “It’s not just the ED care but what happens afterwards on the wards. The specialist trauma wards are more aware now of potential complications and how to deal with them.” (P15)

Peer review of services was felt to be an essential element of clinical governance. There was a desire to improve care by learning from other trauma systems and taking elements of best practice and implementing them locally. “There’s lots of models out there. You don’t have to reinvent everything, but you could take exemplars of best practice from several trauma systems to make the thing work.”

Finally, there was also a desire to become involved in research. It was felt that the new trauma systems provided a perfect opportunity for research, with all hospitals in each region, not just
MTCs, becoming involved. A number of potential research questions were proposed including examining long term patient outcomes and revisiting regional triage tools to improve identification of major trauma in the elderly.

“I think education and injury prevention has been one of the things…so let’s get the practicalities done first and we can address this afterwards, but I think there’s massive scope for projects and improvement. I think it’s just people are trying to do the here and now clinical stuff and get to the rest of it afterwards.” (P1)

The trauma dividend

The implementation of regional trauma systems was seen by all as a positive response to improve the quality of trauma care and patient outcomes. However, on analysis of participants accounts, trauma systems were deemed to have a wider positive impact on the ED as a whole, staff and the hospital.

The unanimous view from all participants was that trauma systems had improved trauma care delivery and had improved patient outcome. However, a view held by staff, particularly in the MTCs, was that trauma systems helped to improve the care of a surprising group of patients – those without injury. As teams from intensive care, anaesthetics and the surgical specialties worked much more closely with ED doctors and nurses in looking after trauma patients, there was a view that these relationships had benefitted patients who may have other serious conditions such as sepsis, brain haemorrhages or intra-abdominal bleeding.

Specialty teams were now used to coming down to the ED (something that was not always the case), learning where things were and who was who. Relationships between the ED teams and the specialty teams were seen to be formed and strengthened. Participants, again, mainly in the MTCs, expressed the view that ‘putting a name to a face’ helped facilitate referrals, expedite care and relieved some of the stress of managing a major trauma (or non-trauma) case as each knew one another’s capabilities.
“I think anaesthetists, general surgical colleagues, orthopaedics are coming down to the department and appreciating the working conditions, the problems we're facing, which I think makes them more empathetic to lack of information, pre-hospital uncertainty, things that they in the past maybe haven't been as forgiving about.” (P3)

Collaboration between ED consultants and other teams to develop trauma protocols and even bid for extra funding at board level were cited as strengthening working relationships that could be called upon when dealing with a sick patient, whatever the pathology. Particularly in the MTCs, having swift access to a CT scanner 24/7 and acute specialties on site overnight to deal with trauma patients also meant they were available to treat non-trauma patients with minimal delay, compared to the past. This was believed to have a positive effect on patient outcomes and also staff morale as sick patients were moved through the ED to intensive care or a place where they would receive definitive care, such as the operating theatre.

All participants felt that being part of a trauma system brought prestige to the hospitals involved, especially to the MTCs themselves. It was seen as a way of securing their services for the future and made staff proud to work there. Participants felt that hospitals that offered trauma services had added ‘status’ and this acted as a ‘draw’ to recruit and retain staff.

“I think certainly being a major trauma centre is a massive badge of prestige actually, because with any new system you keep continually trying to drive up standards and trying to get people to buy in and affecting change. It's a really motivating force. And then I think it's a positive benefit because then you’re attracting and retaining maybe the best quality staff. So in terms of the overall benefit to the Trust, I think it's a massive mark of prestige.” (P17)

Creating a resilient system
As the trauma systems become more mature one recurring concern raised was how the systems were going to maintain resilience to increasing demand, maintaining skills and staff recruitment. These concerns seemed to vary depending on hospital type. Whilst the staff at
MTCs expressed concern about how they would cope with having to treat more seriously
injured, time-critical and resource intensive patients when they are already extremely busy,
others, such as those in TUs, were concerned about losing the skills required to manage trauma
patients. Staff at non-trauma receiving hospitals all pointed out that not everyone comes to
hospital by ambulance and patients ‘still walk through their doors having been stabbed in the
chest.’ Participants at all hospitals felt that the general public have an expectation that all EDs
should be able to deal with major trauma and they have a duty to provide at least a high
standard of initial care before a patient can be transported to a hospital that can offer definitive
care. However, not all were confident that this would be the case, even after the implementation
of trauma systems.

The TUs were seen to have faced particular challenges. These hospitals should be able to
provide a high level of initial trauma care to enable a patient to be stabilised prior to transfer to
a MTC. In the case of a patient with an unstable airway or traumatic cardiac arrest, for example,
time is critical and paramedics may deem to seek these hospitals to provide immediate support.
However, staff felt that as they were seeing less and less trauma on a day-to-day basis they
were now only seeing the extremely sick patients in extremis. They were starting to feel de-
skilled and concerns were raised that colleagues in other specialties were also feeling the same
way.

“We had one chap in who was extremely badly injured and needed intubation (securing
of airway). The consultant anaesthetist did not feel confident carrying out the procedure
in the ED as it was unfamiliar to him and wanted to take the patient to the operating
theatre. I thought that this was a really bad idea and made my views known in the
strongest terms as he was too unstable. He refused, the patient was taken to theatre
but suffered a cardiac arrest in transfer and subsequently died.” (P9)

Quite how such skills can be maintained was the subject of much discussion. It was noted that
it was not just doctors that needed to acquire and retain these skills but the nursing staff too. If
a chest drain is placed by a doctor then the nursing team will need to maintain it and check its
functioning, for example. One way in which participants thought that skills could be maintained was by rotating to the MTCs to gain exposure to injured patients. Some medical staff already do this on an ad-hoc basis to cover trauma team leader shifts at the MTCs but it was felt that this strategy needs to be more widespread and include nursing staff too.

“I would like to see future ED consultants here, actually working in the major trauma system and actually bringing back some policies and procedures and us also getting involved in any, you know, clinical meetings, clinical discussions. Our major trauma systems being led by the Major Trauma Centres.” (P4)

“I think we’re losing skills, such as putting in chest drains all the rest of it. That doesn’t mean to say that that can’t be overcome and I think that, I’m not Clinical Director now, but if we were to, when we attract more further candidates it might well be that we go for a sub group that don’t have an interest in major trauma, or it could be that we have part time contracts and do one major trauma night shift or something over at the Major Trauma Centre. And that would help facilitate our sort of discussions and dialogue with the Major Trauma Centre.” (P4)

“So the sensible or the reasonable option looking at it from that perspective would be that people should work across the hospitals. I think going forward it’s going to become the norm that jobs are shared across sites.” (P3)

Another approach suggested by some, was the creation of a Medical Emergency Response Incident Team (MERIT) that would be staffed by senior trauma doctors and paramedics able to attend the scene of an incident, a local TU or non-trauma receiving hospital, provide clinical support to staff and to then safely transport the patient to a hospital than could offer definitive care.

Perhaps the greatest concern regarding maintaining resilience both of the system and its staff was how each will cope with rising demand. It was recognised by all that providing trauma care
is a stressful experience and that it can have a considerable emotional burden on staff. EDs were felt to be busy enough even without trauma patients who require high levels of human, time and financial resource. Participants at MTCs, in particular, all expressed fears of ‘burn-out’ and some felt that it contributed to high staff attrition rates, particularly amongst nursing staff.

“Without sounding ageist, some of the older nurses who are close to the end of their career, they weren’t very happy about it because it was too much and too intense and too pressurised. They did leave the ED because it wasn’t for them. Like I say, it’s not for everybody, trauma.” (P12)

No solution was offered as to how the volume of trauma patients could be managed, except that many felt that injury prevention strategies needed to play a much greater role as part of trauma systems.

An especially pertinent point was raised by a number of participants as to the role of the system in dealing with a major incident. There was an expectation that all hospitals would be expected to play a role, supporting the view that trauma skills needed to be maintained by all emergency department medical and nursing staff and that a major incident plan should be regularly rehearsed in order to maintain a resilient system in the face of adversity.

“If we have a major incident in the city, you can’t take everyone to (name of MTC)” (P6)

Creating confusion through change
Participants acknowledged that the changes involved in implementing trauma systems had led to confusion for patients, relatives and staff. This view was particularly expressed by participants who worked in Greater Manchester. The causes of confusion centered around four main areas; public awareness of the change, a phased implementation of the system in Greater Manchester, major trauma triage and fear of losing MTC status.
• Public awareness of change

Participants in both regions felt that public awareness of change was poor and that more could have been done before-hand to inform them. The implementation of the trauma system was felt to have led to some confusion from patients and relatives when they were taken to a hospital far away from home rather than to their closest hospital. Experience had made the participants aware of the fact that families sometimes feared the worst when their relative was taken to such a large hospital and, for some, it was very inconvenient. With relatives having further to visit or for patients, discharged after a few hours or so, then having to travel home. This view was expressed particularly by nursing staff in Greater Manchester, where travel times are greater.

“Public perception of the change I don’t think has been handled terribly well, because people are ardent champions of their local EDs. It’s quite a parochial system. There’s a real fight to protect your local emergency department. People want to stay local. You can understand that from visiting times, travel times. And at the point of injury I’m not sure they see the relevance of taking them away somewhere different.” (P7)

“We've had patients sign themselves out because they wouldn't go. I mean some of it's just simple transport problems, they're in (name of place) and they've got an elderly wife or partner at home and they're saying, well how are they going to get to see me if I'm in (name of place) and there's no transport running and we can't afford taxis. I'm not going if you send me there I'm going to sign myself out.” (P3)

• Phased implementation

Perhaps one of the main differences between the implementation of the trauma system in Greater Manchester and Greater London was that it took place in stages. This has previously been described in detail in the Methods chapter. This ‘phased’ approach was the subject of much discussion with participants, many of who had strong views, either in support of such an approach or against. The approach was supported primarily by the
participants who were involved in its conception and implementation. They felt that it was a pragmatic solution that would give confidence to huge change.

“There was a fear in the back of people’s minds around capacity and how we would cope – so in that regard it was useful. People are quite often afraid of change, so to say we’ll do it a bit at a time, see how we go, find out the teething problems, refine it, not quite re-launch it, extend it, I felt there was quite an active process to it.” (P15)

However, others, particularly nursing staff, felt that this approach created confusion, especially for the ambulance service. Concerns were raised regarding patients being taken to ‘the wrong hospital’ either because they were outside of their time frame for being a MTC (e.g. five minutes past five) or patients did not meet the criteria for being treated as a ‘major trauma.’

- **Major trauma triage**
There was an appreciation by all participants that it is difficult for paramedics to identify such patients ‘in the field’ and also that they have pathways to follow for a multitude of medical problems from strokes to heart attacks that involve taking patients to particular hospitals if they meet certain pre-defined criteria. The trauma triage pathways used in both regions were the subject of some strong views, particularly among nursing staff. Cases of ‘over triage’ and ‘under triage’ were recalled by staff at all units but seemed to cause the most angst with staff based at non-trauma receiving hospitals in both regions who felt that they had lost, not only the formal role, but sometimes the capability to deal with such patients and they should not be brought to their units by ambulance.

“They’re saying it fits the pathway we’re saying it doesn’t fit the pathway and it leads to some arguments. They might say, oh he’s had a fall, there’s been no loss of consciousness. Then you go in and he’ll say oh yes I’ve been unconscious for five minutes. So there’s a bit of a discrepancy shall we say. It’s been a long running battle really, basically the ambulance service. I mean they have their pathways which they
tell us a patient fits a certain pathway. I mean we’ve worked together for many, many years, but I think each team is under a lot of pressure themselves and then of course it just ends up causing bad feeling.” (P11)

Participants at both TUs and non-trauma receiving units felt uneasy about ‘refusing’ to accept such patients and directing ambulance crews to MTCs when “there is a patient lying in front of you on a spinal board.” This then led to confusion about how best to manage the patient, the extent of investigations and involvement of specialty teams. Despite protocols, such decisions were not felt to be so straightforward, especially as the MTCs were felt to be extremely busy.

In Greater Manchester, similar frustrations were expressed by participants from the MTCs, where, due to the fact that the three MTCs in the city offered different surgical specialties and interventions, sometimes it was felt that patients were being taken to the ‘wrong’ hospital that could not offer the definitive care required. Despite many having called for a single MTC to service the whole of Greater Manchester, including the expert panel asked to advise NHS North West, a decision was ultimately made to establish three MTCs in the city with two trauma units. Whilst many participants felt that this was a political decision as hospitals did not want to lose precious specialties to others, and led to confusion for patients, relatives and staff, it was defended by participants who were involved in developing the system as a sensible solution that was cost neutral as re-locating services would have cost many millions of pounds.

In comparison, participants in Greater London did not raise such concerns. Despite there being four MTCs in London they all offered the full range of surgical specialties and it was felt that they could deal with all eventualities quite capably. Confusion around patients with particular injuries being taken to particular MTCs was therefore avoided.
• **Fear of further change**

Whilst the rationalisation of trauma care was seen as a positive change by all participants, the threat of further changes concerned participants, especially at the MTCs who felt that they had to justify their role by meeting performance indicators and showing improved patient outcomes, especially through TARN data. Participants in both regions felt that further rationalisation of MTCs was likely in the future and that demand did not warrant the current infra-structure. However, all felt that it should be another MTC that had its status removed rather than their own unit. The threat of change was much more pronounced in Greater Manchester where the region was developing its ‘Healthier Together’ NHS restructuring. The threat of change led to confusion as to the future structure of the recently implemented trauma system.

“Constant changes within the region make it difficult to plan. Who ultimately is making the decisions? Who is in charge? There has been confusion. Goal posts are constantly changing.” (P18)

“So it feels like you’re running on shifting sand. It’s quite unpleasant the amount of uncertainty that there is, and the lack of clarity over who ultimately makes the decision and where that decision’s going to come from.” (P18)

“I’m concerned that if we lose trauma the hospital will be downgraded – we’ll become a Papworth and lose all acute services as they are poached by different hospitals. We all sit here and say it’s been very collaborative across Manchester, it’s been highly competitive, and I think that hasn’t been helpful.” (P19)

**A strong leader**

One of the key factors seen by all participants as essential to successful implementation of the trauma system and also to delivering high quality trauma care, was strong leadership. It was felt that this didn't always need to come from a ED doctor, it could be a nurse or clinician from
outside of the ED. As one participant commented, "you want someone who identifies a problem, knows how to solve the problem and gets the problem solved." (P19)

Even though trauma system implementation was instigated by the NHS and to be delivered by regions within a defined time-frame, there required collaboration not just from other clinical teams and managers within each hospital, but also between hospitals. Emergency Medicine clinicians were acknowledged by all participants to have played a fundamental role in designing and implementing the trauma systems in both regions. All participants, both nursing and medical, expressed the view that for the trauma system to work it was going to need ‘buy in’ from the whole hospital rather than just the ED, even though historically trauma was seen as ‘belonging’ to emergency medicine.

"We needed to have everyone on board. We needed to create a culture that we are a trauma centre not just a hospital that accepts trauma patients." (P16)

"As a doctor you’re very aware that change is driven by the leaders of change, and also they started to be outward looking for the department and it wasn’t that the trauma team leader was always going to be from an emergency department. They got anaesthetic buy in and general surgical buy in, and that seemed to be the spade work that was laid before it rolled out." (P7)

Participants were proud that ‘their’ specialty had taken the lead and was working with others to instigate huge change in trauma care across the region’s, that had been done so successfully for heart attacks and strokes.

Apart from leading organisational change, participants also felt that through the implementation of the trauma systems, particularly in the MTCs, it gave ED clinicians more ‘authority’ to take on more of a assertive, leadership role when managing trauma patients and also to initiate investigations such as CT autonomously. Most felt that it was courses such as the ATLS, the European Trauma Course (ETC) and Trauma Nursing Core Course (TNCC) that gave
individuals the confidence to manage trauma patients in a systematic fashion and to take control of the situation where it had previously been described as a ‘free for all.’

“You could see how they (consultants) would literally stand at the end of the bed rather the head of the bed, because prior to having the systematic team approach you would have the ED consultant with the airway at the top talking down the patient to everybody, whereas now with the trauma team leader role, they’re at the end of the bed, they’re coordinating, facilitating the trauma call rather than actively part of, unless required. I think it works better that way, and I have seen a massive change in that, because rather than being distracted trying to do airway management as well as saying has someone done this, has someone done that, now they can see everyone doing everything.” (P14)

Having a consultant lead the team was seen to expedite the decision-making process and to reduce the potential for delays. Some participants felt that whilst in the past when they were ‘junior’ doctors, it was not quite so easy to enlist the support of other teams or obtain urgent imaging, now that they were consultants, processes seemed to move slightly swifter.

Whilst some participants expressed the view that some team leaders were ‘better’ than others in managing the trauma team and there was still variability they thought that there had been dramatic improvements to the leadership of patients’ initial management and there was now an element of ‘safety netting’ built in. As trauma care has become much more team orientated, participants thought that all team members (including nursing staff) felt empowered to speak up and offer input if they feel something has been overlooked. Care was also seen to be more protocol driven with less chance of clinicians straying too far from what would be thought good practice.

“It was brilliant and one other good thing everyone knew what they were doing and it was the quietest run trauma. You could hear a pin drop because everyone just got on with their jobs. You could hear the team leader without any shouting. We had a scribe that was taking everything. Everyone was talking to the scribe. Everything was
documented and it was because we’d all managed to get together, quick huddle team, setup, and you could hear a pin drop. How a trauma should be run, lovely.” (P14)

**Barriers to delivering high-quality care**

Participants accounts suggest occasional divergence between the care that they offer and the care that they know that they should offer based on a clear understanding of the evidence and local protocols. Analysis of accounts provides a number of factors affecting this implementation of knowledge into practice.

- **Increased service demand**

  All participants expressed the view that demand for emergency care, not just trauma, had increased greatly in the past few years and that the effects of managing a major trauma patient can be profound on an already busy ED. Participants who worked at MTCs felt that they were seeing increased numbers of major trauma patients, particularly the elderly. Such demand placed extra stress on nursing and medical staff as they felt that they were not able to offer the quality of care that they should be giving. Participants felt their departments were under-resourced and this was contributing to delays in patient care. Some participants felt uneasy that trauma patients seemed to take priority over patients with sepsis or asthma and best practice tariffs were driving this behavior.

  “Major trauma grinds the department to a halt quite easily” (14)

  “And unfortunately, at the moment with the economy being what it is, they do not want to build redundancy into the system, and you do need an element of redundancy to deliver excellent trauma care” (P17)

- **Change in demographic - ‘Silver trauma’**

  Participants from all units expressly commented on the change in trauma patient profile seen over the last few years with more and more elderly patients presenting with injuries,
sometimes major injuries, particularly following falls. Many participants gave examples of such patients with seemingly innocuous injuries who turned out, after imaging, to have suffered major trauma. Consequently, many participants had now adopted a much lower threshold for CT scanning the injured elderly population. This change in demographic was seen to place significant demands on EDs as the elderly were generally noted to have greater care needs than younger patients. Participants from TUs and non-trauma receiving hospitals felt that, on some occasions, after they had identified serious injury, the MTCs were reluctant to take over their care. This group felt that the strategies for the management of the elderly should be a priority for both trauma systems, including developing experts with a special interest in their management.

- **Staffing**

  Whilst participants acknowledged that recruitment to the EDs of MTCs for both medical and nursing roles had been improved by trauma system implementation, this was at the expense of the TUs and non-trauma receiving hospitals that were having significant difficulty recruiting and retaining staff.

  "I have concerns now that as a trauma unit we’ve not managed to recruit a consultant post in three years. I’m well aware that most of the current trainees are going to, you know, the major teaching hospitals. Now I think the loss of major trauma has something to do with it." (P4)

However, participants from MTCs, especially the nursing staff, raised concerns that the increased volume of patients, the high levels of stress placed on staff and concerns about the quality of care being able to be offered could start to place significant pressures on staff retention, as has already been seen at one MTC. The concept of ‘burn-out’ was also raised by medical participants who all felt that managing trauma was a stressful job and could not be done ‘day in, day out’ without significant ill effects.
“People want to work in trauma but only if we do it right with adequate staffing levels and the right work-life balance” (P11)

- **Services and skills**

Whilst participants who worked in MTCs felt that they had most of the skills available to manage most severely injured patients, this was not the case in TUs where participants felt de-skilled and sometimes unsupported by their regional MTC.

“They’re getting the extremes of trauma really, and I don’t think they’re particularly well equipped to look at the extremely ill patients because they’re not fully set up.” (P19)

Participants, particularly at the non-trauma receiving hospitals found dealing with trauma patients extremely stressful and felt out of their ‘comfort zone.’ They acknowledged that whilst before trauma systems implementation they used to see and manage trauma patients, the resources available to them had since changed and they felt unable to manage their needs.

“I mean it’s very stressful, I find it very stressful. I mean we unfortunately don’t have the nursing staff on the shop floor to actually care for people that are quite unwell. We don’t have the right equipment, skills, drugs or staff to manage a major trauma at our hospital any more” (P13)

- **Dedicated trauma treatment area**

A number of participants who worked at MTCs felt that as they develop, separate major trauma treatment areas should be considered, away from the ‘main’ ED. They proposed that this area would be staffed separately to the ED with staff seconded from other hospitals from within the trauma system to encourage cross collaboration. The participants felt that it was not ideal to treat trauma and non-trauma patients together and that it could impact on the care of the non-trauma patient as well as being an added stressor for them.
“I think there is an impact on non-trauma patients like those with a stroke being managed in a trauma centre where the trauma load, the trauma case mix is high, it distorts their patient pathways such as the time it takes to get a CT” (P15)

“I can imagine it’s quite scary, because obviously the tannoy goes, red standby, ETA, and that can be quite frightening. However, if you have that one patient in the corner who’s not a trauma patient then you see everybody gravitate… So you may only have one doctor looking after you, one nurse, if you’re a non-trauma patient. However, when a trauma comes in they’ve ten doctors and three nurses in there and you could be thinking what’s going on, have I been left out?” (P5)

Summary

This chapter presented the results of twenty interviews with participants who worked in EDs in Greater London and Greater Manchester. The departments offered a variety of trauma care services to reflect a combination of perspectives from frequently accessed services. Seven dominant themes were raised. The accounts illustrate how service provider perspectives can improve our understanding of the current situation and inform future change. In the following chapter, I will discuss these results in detail before presenting a triangulation analysis combining the qualitative results presented here with the quantitative data presented in the previous chapter.

Box 3: Summary of key qualitative study findings

What is already known on this topic?
- There is very little published qualitative research examining the implementation and functioning of trauma systems.
- The only UK study highlights the discrepancy between the care NHS nurses want to provide to trauma patients on the ward compared to the level of care they are able to provide.

What this study adds
- This is the first qualitative study to examine the effects of implementing a trauma system
- System implementation was well received and felt long overdue
- Staff unanimously felt the trauma system had improved care and outcomes
- The trauma system was perceived to improve care for non-trauma patients
- Many staff outside major trauma centres feel de-skilled and disenfranchised
Chapter 6: Discussion
The aim of this study was to critically assess the implementation of inclusive trauma systems on processes and outcomes of care in two regions of England. To enable a broader exploration and analysis of the research problem, a mix of both quantitative and qualitative methods were used:

- A systematic review of the literature was undertaken. This posed the review question, "In adults who have sustained a serious injury, does treatment within a ‘inclusive’ trauma system result in reduced mortality and disability, compared to receiving treatment in an ‘exclusive’ trauma system or ‘standard care’."

- Using data obtained from the Office for National Statistics (ONS) and the Trauma Audit and Research Network (TARN) the following quantitative analyses were presented:
  - A description of the epidemiology of trauma deaths in the three study regions over time
  - An analysis of patient outcomes and hospital process measures in Major Trauma Centres (MTCs) before and after the implementation of trauma systems in two regions of England, using South Wales as a comparator region
  - A time-series analysis of patient outcomes and hospital process measures from two years before trauma system implementation to two years after, in two regions of England encompassing data gathered from all hospital types that received injured patients

- An analysis of 20 semi-structured interviews following a purposive sample of National Health Service (NHS) staff who provided trauma care to patients in Greater London and Greater Manchester, before, during and after trauma system implementation. After exploring their views to gain an understanding of the impact of such a system and to explore the drivers and barriers to successful implementation and operation, dominant themes were presented.
Box 4: Summary of key findings

What is already known on this topic?

- Trauma causes a significant number of deaths, increasingly affecting the elderly
- Falls are overtaking vehicle collisions as the primary cause of trauma
- There are many studies, mainly of poor methodological quality, showing a survival advantage when trauma systems are introduced to a population
- There is very little published qualitative research examining the implementation and functioning of trauma systems.
- The only UK study highlights the discrepancy between the care NHS nurses want to provide to trauma patients on the ward compared to the level of care they are able to provide.

What this study adds

- Uses a novel dataset to add to the body of evidence that trauma patients are becoming older
- Identifies a considerable burden of trauma death outside of hospital
- Standardised rate of survival shows upward trend over time in regions that have implemented a trauma system compared to those that have not
- Process measures such as time to CT scan are reduced following system implementation
- A greater proportion of seriously injured patients are now being treated in major trauma centres
- This is the first qualitative study to examine the effects of implementing a trauma system
- System implementation was well received and felt long overdue
- Staff unanimously felt the trauma system had improved care and outcomes
- The trauma system was perceived to improve care for non-trauma patients
- Many staff outside major trauma centres feel de-skilled and disenfranchised

The results of these analyses have been presented in the previous three chapters. However, the major findings were as follows:

The systematic review identified eight observational studies that examined the effect of trauma system implementation on patient outcome. All demonstrated a significant reduction in the odds of death following the implementation of such a system, however, methodologically they represented a low-quality body of evidence.

Study one: Utilising data gathered from the ONS, the epidemiology of trauma deaths in Greater London, Greater Manchester and South Wales was described and demonstrated:
• The majority of trauma deaths occurred in the elderly population
• Men, especially younger men, were more frequently killed by injury than women
• Annual crude mortality rates were stable except in Greater London where rates were consistently lower and falling
• 30-50% of trauma deaths occurred outside of hospital

Study two: Before and after study with comparator region

The main research findings were as follows:

• The number of cases submitted to TARN increased over time, especially in the regions that implemented trauma systems
• The majority of injured were male and secondary to falls
• The proportion of patients receiving consultant delivered care increased in all three regions
• Other process measures, such as time to CT, showed a demonstrable improvement in regions that adopted MTCs compared to the comparator region
• Standardised rates of survival showed a statistically significant improvement in both Greater London and Greater Manchester following MTC implementation, compared to the comparator region

Study three: Time-series analysis

The main research findings were as follows:

• The number of cases submitted to TARN increased over time, particularly since trauma system implementation
• Males were predominately affected, with falls increasing over time and motor vehicle collisions falling
• The median age of those injured increased over time in both regions
• Whilst in Greater London the ISS fell over time, it increased significantly in Greater Manchester
• In the period following trauma system implementation, increased proportions of adults and children were transported directly to a MTC, with fewer seriously injured patients receiving care entirely outside a MTC
• Process measures such as time to CT and the proportion of patients attended to by a consultant on arrival to hospital, showed marked improvement in the years following trauma system implementation, especially in Greater Manchester
• Standardised rates of survival improved in both regions in the period following trauma system introduction, however, the change was only statistically significant in Greater London

Study four: Qualitative study
The qualitative study identified seven main themes and a number of sub-themes;
• The need for change
  o Delay
  o Unreliable care
  o Lack of organisational structure
• Knowledge
• The trauma dividend
• Creating a resilient system
• Creating confusion through change
  o Public awareness of change
  o Phased implementation
  o Major trauma triage
  o Fear of further change
• A strong leader
• Barriers to delivering high-quality care
  o Increased service demand
  o Change in demographic – ‘Silver trauma’
  o Staffing
  o Services and skills
Study five: Integration of data

To enable integration of data from multiple sources and methods, data were merged in relation to seven specific themes identified. The process was outlined in the Methods chapter. Each theme will be discussed separately, highlighting areas of convergence and dissonance between data sources.

A change in trauma epidemiology

A meta-theme evident from analysis of all of the data was agreement that the trauma population is increasing in age. Analysis of the ONS data showed that in all three regions studied, the majority of trauma deaths occur in those aged over 80 years. In Greater Manchester, 52% of trauma deaths were in those aged over 70 years between 2006-2014. Both of the TARN data analyses demonstrated a change over time with the time-series analysis demonstrating median age increasing from 42 to 54.8 years between 2008/9 and 2011/12 (p<0.05) in Greater London and from 56.3 to 62.1 years between 2013/14 and 2010/11 (p<0.05) in Greater Manchester. Analysis of interviews with NHS ED staff demonstrates complementarity with the quantitative data with staff reporting a noticeable increase in the number of elderly patients treated in all hospital types. Many nurses felt that they have increased care needs compared to younger patients and doctors highlighted the concern that the elderly population can present with significant injury even despite a seemingly innocuous injury mechanism, leading to patients being ‘under-triaged’ to TUs and non-trauma receiving hospitals, when, in fact, they should have gone directly to a MTC when their injury profile eventually comes to light, usually after CT scanning. Unfortunately, this study did not examine for this effect although the sensitivity of triage tools in identifying serious injury in the elderly population has been questioned by multiple studies, including a multi-centre US study that demonstrated a progressive fall in triage tool sensitivity for each decade beyond 60 years.\textsuperscript{8}
A study by Kehoe et al\textsuperscript{9} in 2015 that interrogated the TARN database to identify all major trauma cases (ISS$\geq$15) between 1990 and 2013 found that the mean age increased from 36.1 to 53.8 years over this time-frame and suggested that rather than being a disease of ‘young-men’ the majority of those seriously injured in the UK are over 50 years. This trend is not limited to the UK and has been seen in many other countries, including the USA.\textsuperscript{10,11}

As the population ages and people become frailer it is perhaps inevitable that hospitals are going to treat more and more elderly people. Whilst there is no doubt that the proportion of trauma patients who are elderly is increasing, the increased numbers seen could, in part, be due to improved imaging and the identification of injuries that may have not been picked up in the past. Previously, an elderly patient who fell down stairs may have had an X-ray of the injured area, now such patients are increasingly having whole body CT scans that have an increased diagnostic yield and identifying injuries so that these patients now meet TARN, or other injury database, inclusion criteria.

As the trauma population has changed in age, so has the mechanism of injury. It is noticeable in this study that there has also been an increasing trend in falls over the study period, away from MVCs. The time-series analysis of TARN data demonstrated an increase in falls <2 metres in both regions, with Greater London seeing an increase from 21% (95% CI 19-23.1) to 44.6% (95% CI 43.4-45.9) from 2008/9 to 2011/12 and Greater Manchester seeing an increase from 56.8% (95% CI 54.5-58.9) to 63.2% (95% CI 61.3-65.1) between 2011/12 and 2012/13. This change over time is also seen by others, with one UK study, also of the TARN database, reporting an increase of low falls from 4.7% in 1990 to 39.1% in 2013.\textsuperscript{9}

Whilst there may be a perception, certainly outside of medicine, that ‘major trauma’ is a disease of the young and caused by shootings, stabbings and motor vehicle collisions, perhaps led by TV dramas and news-reports, in reality, trauma is now a disease of the elderly and mostly caused by falls. Hospitals of all varieties will have to develop strategies to meet their needs as will trauma systems, to enable the markers of significant injury to be identified at triage so that elderly patients can be treated at the most appropriate facility. Whilst legislation and improved
car design likely had a huge impact in reducing injury and deaths from MVCs, minds will have to be turned toward falls prevention strategies and the like to reduce the impact of this seemingly simple mechanism of injury.

Out of hospital deaths

Between 2006 and 2014, ONS data showed that around 30-50% of trauma deaths each year were outside of hospital, with the proportion in Greater London and South Wales being around 10% more than Greater Manchester. In 2014, 1296 people died outside of hospital, and, overall more males aged 20-29 died outside of hospital than within. There is a sparsity of research into pre-hospital deaths, particularly in the UK, however, a study by Hussain and Redmond in 1994 found that up to 39% of pre-hospital deaths from accidental injury may have been preventable. A large US study of trauma deaths in seven states showed that 37% of deaths occurred in the pre-hospital phase but figures up to 86% have been reported. Indeed, a population based cohort study in Sweden showed that for every person younger than 65 years who died in hospital, there were nine pre-hospital deaths. Oliver et al discuss the concept of a ‘therapeutic vacuum’ between the time of injury and the arrival of the emergency services. In their study of pre-hospital deaths in Cheshire, UK, they demonstrated that a bystander was at scene at the time or there within minutes but only 25% of those carried out any first aid intervention.

Trauma system care seems biased toward hospital based treatments and the distribution of resources reflects this. This is supported by the fact that, apart from the ONS data, it was not identified as a concern on analysis of the other data sources that remained silent on the issue. Whether this is due to a lack of appreciation as to the scale of the problem, a perception that many of these patients would be unsalvageable or that strategies to reduce this burden of death would be difficult to implement, is unknown. What is demonstrated is that many trauma patients do not survive long enough to benefit from hospital based care. However, is there a limit to what medicine can do? Many of these deaths may be due to domestic violence, suicide or gang culture and solutions may be thought to be outside of medicine’s remit, requiring much wider changes in society or Government policy. However, through at least identifying the population
and causes we can flag them, push for change and work with others to bring about such change as has been done successfully by medicine in the past with regards to smoking and drink-driving.

After all, injury prevention and pre-hospital care are vital elements of inclusive trauma systems and reducing the burden of trauma across the whole population, not just reducing the in-hospital mortality rate, is a key quality indicator. Perhaps some of the biggest gains in reducing trauma deaths are to be sought here.

**An increased demand for trauma care**

There was partial agreement across data sources around the theme of increased demand for trauma care. Interview participants who worked at MTCs expressed the view that they were seeing more and more trauma patients and that this was putting a strain on the quality of care that they could offer all patients, the efficiency of the department as a whole and increased stress levels and ‘burn-out’ of staff. They felt, nurses in particular, that they were under-resourced and that the increased demand and workload was having a negative effect on staff retention and their own well-being. Whilst staff at TUs and non-trauma receiving hospitals still received cases that they felt shouldn’t be there, placing additional demands on the department and staff, there was agreement that they were seeing less trauma than they did. Of course, this is the aim of an inclusive trauma system – that seriously injured patients should be taken directly to a MTC to receive definitive care.

Both analyses of the TARN data show a striking increase in submissions to TARN over the study period. In the before and after study of MTCs, Greater London increased submissions by 37% for children and 82% for adults whilst South Wales noted a 4% increase and 7.7% fall respectively. However, in the time period that Greater Manchester was studied (2010-12 and 2012-14), paediatric submissions increased by 61.5% and adults only by 17.5%. In contrast, South Wales increased 79.7% in children and 124% in adults. In the time series analysis of
Greater London and Greater Manchester both paediatric and adult submissions increased over time. However, as discussed later in the limitations section of the discussion, the increased submissions may not reflect a true increase in trauma patients, as MTCs were financially incentivised to submit data to TARN through the best practice tariff. The ONS data also does not show an increased trend in hospital death over these time-frames, as would be expected if the total number of injuries increased so dramatically in all these regions.

However, there is corroboration between interview participants views on specific service demand and TARN data. In Greater London, the proportion of all injured patients taken to a MTC increased from 31.7% (95% CI 27.4-32) in 2008/9 to 57.2% (95% CI 55.1-57.6) in 2011/12 whilst in Greater Manchester the proportion increased from 28.7% (95% CI 26.8-30.9) in 2010/11 to 51.8% (95% CI 49.9-53.8) in 2013/14. This statistically significant increase was mirrored in both regions when a sub-group of the most seriously injured were examined (ISS ≥15). The proportion of this group of patients to be treated entirely outside a MTC also fell from 36.2% (95% CI 13.6-16.3) to 17.6% (95% CI 5.9-7.1) in Greater London and from 40.3% (95% CI 9.7-12.8) to 14.9% (95% CI 4.2-6) in Greater Manchester. This change was also found in the paediatric population.

Whilst in both regions, increased numbers of trauma patients, including those seriously injured, are taken directly to a MTC and less are treated entirely outside of a MTC, there is still a large proportion of patients not being managed in accordance with system guidelines. This will be discussed later. Two previous studies of regionalisation of trauma care in England also noted an apparent increase in patients treated in MTCs, one study noting a 62% increase whilst the other demonstrated an increase from 16% of seriously injured patients being taken directly to a MTC, to 84% after service reorganisation.

This study has shown that the volume of trauma patients increased at MTCs and fallen at TUs and non-trauma receiving hospitals in both regions, supporting the views of NHS staff. As demand increases at MTCs commissioners and managers of emergency services should ensure that appropriate levels of nursing, medical and ancillary staff are available to provide a
high quality of care for patients whilst also developing strategies to maintain staff morale and avoiding ‘burn-out.’ Such strategies may help to reduce high-levels of staff turn-over, particularly within the nursing population.

**MTCs are the main beneficiary of a trauma system**

Whilst an inclusive trauma system should be more than just trauma centres, there was partial agreement across data sources that the sole beneficiary of trauma care reorganisation has been the MTCs, whilst other hospitals and have been ‘left out.’ Interview participants based at MTCs talked of the prestige of working there, the attraction that the centre now had for recruiting the ‘best’ staff and their confidence that the MTC would survive further reorganisation as long as it continued to offer high quality care and good patient outcomes, compared to others.

In contrast, staff at TUs and non-trauma receiving hospitals felt that they had been ‘downgraded’ and were now at an increased risk of losing any other specialist services that remained at their hospital to the larger MTC and even increased their risk of closure or, at least, losing their ED and becoming an urgent care centre. Senior doctors in particular felt that recruitment of new consultants was also a problem as many wanted to work at a MTC and they would have to develop novel strategies to enhance the attractiveness of a role. This was viewed as less of a problem by nursing staff who, perhaps, are more mobile and more frequently change jobs or locations than consultants, many of whom remain in the same hospital following their initial appointment.

Instead of EDs and hospitals working together as part of a system, many staff from TUs and non-trauma receiving hospitals saw themselves as far removed from what was happening at the MTC. They felt there was a lack of communication and collaboration with projects such as education and research, and the process had been more competitive and soured relations between hospitals, particularly in Greater Manchester. MTCs were also viewed to have benefitted financially from the reorganisation in the form of being rewarded for meeting quality indicators through the best practice tariff and also through capital investment, a view particularly
expressed by non-MTC staff in Greater London. Such dissenting voices from those based in TU's and non-trauma receiving hospitals is a matter of concern in a system that is supposed to be 'inclusive' and where one of the key facets of the system is working together as a team for the benefit of the patient and following standardised regional guidelines.

ONS and TARN data did not measure indices that would allow corroboration of these views, however, documentary evidence confirms the view that the best practice tariff only benefits MTCs and the fact that MTCs in London did receive significant capital investment prior to trauma system reorganisation. MTCs in both regions also received added investment through local NHS trusts to expand consultant numbers, to allow enhanced consultant delivered trauma care.

Whilst MTCs have perhaps been a beneficiary in many ways, MTC status also undoubtedly puts added pressure on the host organisation in terms of increased demand on services. Whilst MTCs should be adequately recompensed for delivering expensive trauma care, for trauma systems to function optimally and as planned, there needs to be improved communication and collaboration between all parties to enhance the partnership for all, particularly patients.

**Inclusive trauma systems reduce mortality**

A meta-theme where most data support this assertion. The call for improvements to trauma care in the UK has been long-running and NHS staff interviewed felt that prior to the implementation of trauma systems, patients were dying when they shouldn't have been. Most staff were aware of the evidence behind trauma systems and that they had been shown to improve outcomes. This was particularly the view expressed by staff who worked in the military who could compare outcomes between their civilian and military practice. Staff were confident that since the introduction of a trauma system in their region that mortality had improved and that patients were now surviving that might not have done so even only a few years ago.
Mortality data from the ONS showed population standardised mortality rates to be relatively stable although a downward trend can be seen in Greater London where mortality fell from 19.5/100,000 in 2006 to 15.3/100,000 in 2014. Greater Manchester and South Wales demonstrated higher rates, with Greater Manchester registering 31.4/100,000 deaths in 2009 compared to 28.6/100,000 in 2014. It is impossible to conclude that any fall seen is secondary to the introduction of trauma systems but it is of note that rates are lower in Greater London than the other study regions. This may be due to Greater London having a younger population than Greater Manchester and South Wales.

Analyses of the TARN data certainly supports the view of staff that mortality rates have decreased since trauma systems have been implemented, and the standardised rate of survival has shown steady improvement over time since implementation of the trauma systems in Greater London and Manchester. In fact, the before and after study of MTCs showed that whilst the standardised rate of survival did not change over time in South Wales, Greater London saw an increase from -0.81 (1.8-0.56) in 2008/9 to 1.84 (0.21-2.1) in 2012/13. A similar increase was also seen in Greater Manchester from -1.83 (-3.4, -0.26) in 2011/12 to 1.09 (0.21-1.96) in 2013/14. However, whilst the time series analysis of all hospital types within the trauma system showed a statistically significant improvement in Greater London from -0.45 (-1.38-0.48) in 2008/9 to 0.52 (0.05-0.99) in 2011/12, this was not seen in Greater Manchester, even though there was evidence of improvement (-1.13 (-2.4-0.12) in 2010/11 to 0.67 (-0.02-1.36 in 2013/14).

The potential causes of the statistically significant improvement seen at Greater Manchester MTCs but not within the system as a whole is likely to be multifactorial. It could reflect the fact that mortality at TUs and non-trauma receiving hospitals has not improved, or has even increased, since system implementation. As transport times are potentially longer in Greater Manchester than in Greater London this may well lead to more seriously injured patients are taken to TUs for stabilisation before onward transfer to a MTC. If patients are not receiving high quality trauma care across the TUs then this could impact on outcomes for the whole system.
Overall, however, this study supports the evidence provided by others that inclusive trauma systems, and particularly MTCs, improve mortality.\textsuperscript{1,2,19} However, in contrast to many studies that show that the benefits of the regionalisation of trauma care takes many years to become apparent,\textsuperscript{20,21} we have demonstrated improvement within two years of implementation. A before and after study by Claridge et al\textsuperscript{6} that examined the effect of implementing the North Ohio trauma system two years before and two years after, the same time frame as this study, also found that treatment in the post system implementation group was an independent predictor of survival. If the current evidence stands, outcomes should continue to improve over time.

**Inclusive trauma systems increase the quality of care**

Whilst mortality has been shown to improve, the study also explored potential reasons as to why this might be the case and what particular elements of a trauma system might be responsible for such change. Analysis of interviews of NHS staff showed that there was a unanimous view that the delivery and quality of trauma care needed to improve as it was seen to be unreliable and beset with delay. Both nurses and doctors agreed that the quality of care that a patient received was often dependent on what time of the day or night they presented, where they presented and who treated them. This approach was felt to have been unacceptable and associated with worse outcomes. A recent study by Beckett et al supports this view.\textsuperscript{22} The study explored the views of NHS staff who provided trauma care in three regions of England and found that they described two distinct models of trauma care. The ‘ideal’ model consistent with delivering high quality, evidence based trauma care that they wanted to provide, and a ‘real’ model, frequently provided, which was “fragmented, inequitable and had major gaps in its provision.” Whilst NHS staff in both of these studies had the knowledge that care was not as good as it could have been, the organisational structure and processes were not in place to allow this optimum level of care to be delivered. The relationship between structure, process and outcome was initially described by Donabedian\textsuperscript{23} and according to this model, improvements in the structure of care should lead to improvements in clinical processes that then lead to improved patient outcomes. The model has recently been validated for use in
evaluating trauma care by Moore et al, who found that “efforts to improve structures and processes of care may have a positive effect on patient mortality, morbidity and resource use.”

Since the implementation of regional trauma systems in both regions studied here involved significant changes to the organisation of services and the implementation of evidence-based protocols, Donabedian’s model would predict improvements in outcome. Whilst it has been demonstrated that mortality has been reduced, most staff felt that the quality of care had also improved. In fact, all data sources, (with the exception of ONS data that did not examine quality of care indices) agreed that inclusive trauma systems led to an increase in the quality of care delivered to injured patients, certainly at MTCs. There was some disagreement between the data when examining the effect at non-MTC hospitals. Staff, particularly those who worked in TUs and non-trauma receiving hospitals in Greater Manchester, were concerned that they did not have the facilities or skills to manage trauma patients and felt quite isolated. Whilst staff at TUs felt that as they were seeing less trauma patients since the system was implemented they were losing the skills required to optimally manage them. This ‘de-skilling’ was seen to affect both medical and nursing staff, from within the ED and beyond. TU staff also felt that the trauma patients that were taken to them were sometimes a sub-set of the most severely injured patients who were not thought able to survive the longer direct transport to a MTC. This was seen to put added pressure on staff who were now less experienced and confident with managing such situations. Consequently, they felt that the care offered to these patients sometimes remained sub-optimal.

Those ED staff who worked at non-trauma receiving hospitals all felt that there was an expectation from the public that all EDs should be able to manage a patient with major injury. However, some felt that this expectation was not reality. They felt that trauma patients should not be taken to them by the ambulance service but they were still doing so. This then led to conflict between ED and pre-hospital care staff and delays in arranging definitive care if serious injuries were identified. It was acknowledged that the care able to be provided to seriously injured patients would not be as good as if they were treated at a MTC and staff felt that they
sometimes struggled with MTCs and pre-hospital care teams, whilst they acted as the patient’s advocate.

The TARN data supports the view that in both regions more and more patients, adults and children, are being taken directly to MTC, including those most seriously injured that could lead to TU staff seeing less trauma patients and becoming de-skilled. However, the analysis also shows that whilst the proportion of ISS ≥15 adult patients treated outside a MTC has fallen from 36.2% (95% CI 13.6-16.3) to 17.6% (95% CI 5.9-7.1) in Greater London and from 40.3% (95% CI 9.7-12.8) to 14.9% (95% CI 4.2-6) in Greater Manchester, there remains a large proportion of trauma patients who should have been treated at a MTC but were not. This group of patients may be receiving less optimal care and it is of concern that this is acknowledged by staff at TUs and non-trauma receiving hospitals. It is also concerning that non-MTC staff often feel unsupported and strategies need to be introduced to support them whether through the role of enhanced training, rotations to work at MTCs or through bringing advanced trauma care outside of the MTC through the use of Medical Emergency Response Incident Teams (MERIT) team and retrieval services. There is also a need to regularly audit regional triage tools to ensure that seriously injured patients are taken directly to the most appropriate care facility. The development and introduction of an evidence based national triage tool may go some way in improving this.

In both regions, the main factors credited with the perceived improvement in the quality of care and outcomes were reduced delays to investigations and definitive care and the presence of a senior clinician who could manage the team in a structured and confident manner. Examples of delays included patients waiting for a CT scan, to take a patient to the operating theatre or even waiting for a consultant to attend the ED from home. Delays were not only felt to contribute to poor quality of care and poorer outcomes but also added to staff anxiety and dissatisfaction about their job. One perceived marker of improved care was the role of CT scans – both in the increased use of such imaging and the time taken for a patient to have the scan after arrival in the ED. Expeditious CT scanning was viewed as a way of identifying injuries early on, to then support decision making around organising definitive care, such as the need for surgery or
transfer to a MTC. Several studies support this view, with improved patient survival, more accurate injury diagnosis and shorter time to definitive diagnosis being contributed to the use of CT in trauma patients\textsuperscript{27,28} although one recent study examining the use of CT in UK trauma hospitals found wide variation in its use, with TUs utilising CT less than MTCs.\textsuperscript{29}

Since trauma system implementation delays were perceived to have reduced, particularly by staff at MTCs. Analysis of TARN data supports this view, with time to CT falling, particularly in Greater Manchester with time taken to CT falling from 3.5hrs to 1.94hrs (p<0.005) in adults and from 7.9hrs to 0.9hrs (p<0.005) in children in the before and after MTC groups, respectively. This fall was also demonstrated in the time series analysis of the whole Greater Manchester trauma system with time to CT for adult patients falling from 3.4hrs in 2010/11 to 1.9 hours in 2013/14 (p<0.05) and from 4.9hrs to 0.7hrs (p<0.05) over the same time-frame in children. A significant fall in time taken to CT was not demonstrated in Greater London through either study. This may have been due to the fact that their times were already impressive compared to others and there may be a limit to what can, or should, be achieved as patients should be assessed and stabilised before going to scan.

NHS ED staff also felt strongly that it was increased seniority of the clinician managing the trauma patient’s care from the outset that contributed to improved outcome. Someone who had the knowledge, skill and authority to lead a trauma team in a systematic fashion. Staff in MTCs in both study regions felt that since trauma system implementation, an increased proportion of patients were being seen by a consultant in the ED and this view was supported by analysis of TARN data with a statistically significant increase seen in both adults and children in both the before and after study of MTCs and also the time-series analysis. However, in Greater London, whilst the proportion of adults seen by a consultant increased from 61.6% (95% CI 59.4-74.4) to 90.7% (95% CI 89.8-91.7) in the MTC group studied for the before and after analysis, in the time series analysis, where all hospitals were included, the proportion fell with only 33.2% (95% CI 30.9-35.6) initially seeing a consultant, increasing to 40% (95% CI 39.4-41.9) after system implementation. A similar pattern was seen in Greater Manchester with 60% (95% CI 60.4-64) of adults seeing a consultant at MTCs two years after implementation, compared to 28.9%
(26.2-31) before but only 46.2% (95% CI 44.2-48.2) of adults seeing a consultant in the system as a whole, from 18.9% (95% CI 17.1-20.9) before implementation.

The effect on patient outcome of having a consultant deliver care has been studied in many areas of medicine although the overall effects have been inconclusive. One UK study found that patients presenting with major trauma had improved outcomes\textsuperscript{30} whilst other studies from the USA showed that whilst the availability of a consultant trauma surgeon reduced resuscitation time and time to incision for surgery, it had no impact on patient mortality.\textsuperscript{31} Whilst many interview participants felt that, in the past, care might have been worse at night or on the weekend, a recent study by Metcalfe et al of English MTCs with 24-hour consultant presence could find no effect of worse patient outcomes at the weekend after adjusting for confounders.\textsuperscript{32}

In the comparator region of South Wales, some markers of quality also increased without a formal trauma system being implemented. More patients were seen by a consultant, increasing from 34.5% (95% CI 31.3-37.7) in 2008-10 to 47.4% (95% CI 44-50.7) in 2010-12. However, these changes may well have been driven by recommendations from organisations such as the Royal College of Emergency Medicine that EDs should have consultant presence for at least 14 hours a day seven days a week, rather than strategies taken to specifically to improve trauma care.\textsuperscript{33}

Ultimately, the study shows that these perceived quality markers have indeed improved since trauma system implementation. Interestingly, staff felt that the structure and process changes that have taken place have not only benefitted trauma patients, but non-trauma patients too, although this was not explored further here.

**Successful implementation of change**

It is hoped that the research presented in this thesis will add to the body of knowledge around inclusive trauma systems and assist those contemplating the introduction of such a system or seeking to optimise their current model of care. By studying Greater London and Greater
Manchester it enabled comparison of slightly different organisational systems and methods of implementation. There was partial agreement across the data sources although ONS data could not be used to provide corroboration as it solely focused on mortality. Whilst the implementation of the system was praised in Greater London, where it became operational overnight, staff in Greater Manchester felt that having a phased implementation was, on the whole, a mistake. Those clinicians who instigated this plan were confident that a phased response allowed individual hospitals to cope and safely meet demand. However, other clinicians and nursing staff, even from the MTCs, felt that it led to unnecessary confusion amongst pre-hospital care staff and ED staff themselves about which patients should be going where and when. This was seen by many as leading to increased animosity between other hospitals and pre-hospital care staff. Most participants in Greater Manchester felt, in retrospect, that full trauma system introduction at a single point in time would have been preferential.

In Greater Manchester, establishing three MTCs was also viewed with some controversy by staff working in the region. Most staff felt that all surgical specialties should be provided by a MTC – this included neuro-surgery, cardio-thoracic surgery and vascular surgery and appreciated that all of these services were not provided by any single centre. Most felt that reorganisation of services would have been optimal to having three MTCs which they felt led to confusion for pre-hospital care staff, ED staff and patients about which patients should be taken where. Despite there being four MTCs in Greater London, the theme of confusion was not so apparent, perhaps because each MTC had the full spectrum of services deemed necessary by those interviewed.

The lack of public awareness of change was also raised in both regions, but more so in Greater Manchester. Many staff here, particularly nurses, felt that patients and their relatives were sometimes surprised to find that they had been taken to a centre far from home. This then led to practical concerns about how they were going to get home or visit. Whilst they felt that most appreciated why they had been taken to a MTC or TU, some refused to go or felt that these services should be available at their local ED. In London, this view was not so prevalent among staff, perhaps due to the shorter transport times and enhanced public transport available.
A final recommendation highlighted from the interviews in both regions was the potential role of a dedicated trauma treatment area, outside of the main ED resuscitation room. Concern was raised about the disruptive effect that major trauma can have on the whole department, with staff being ‘pulled away’ from other ill non-trauma patients or staff with an interest in trauma wanting to get actively involved. One participant felt that a major trauma patient could “bring the department to a grinding halt” and some thought that trauma patients being treated in the same area as others could have a negative impact on their care. There is some published evidence to support this view. Smith et al studied the effect of trauma activations in the ED on non-trauma patients and found that the median time from patient arrival to evaluation by a doctor was almost twice as long as for those unaffected by a trauma patient arrival (42 vs 23 minutes, p<0.001).34 Times from arrival to X-ray, CT and laboratory results were all significantly longer as was length of stay in the ED. Another study examining the effect of concurrent trauma patient arrival on patients presenting with potential acute coronary syndrome found concurrent trauma activation to be independently associated with increased rate of 30-day cardio-vascular complications (OR 1.72, 95% CI 1.01-2.92).35 Consequently, as EDs are re-designed and new facilities built, consideration should be given to stand-alone trauma treatment areas that would confine and focus staff based inside and out of this area.

**Strengths and limitations**

One of the principle strengths of the study was the use of mixed methods to provide a much broader understanding of the research question. Whilst the quantitative data enabled an analysis of process measures and outcomes the qualitative analysis was able to afford information about the context of behaviours. Whilst demonstrating that trauma systems improve patient outcome, the qualitative analysis gave insight into why this might be the case. Corroboration of the view that it was, for example, due to reduced time to CT and increased consultant delivered care, with quantitative data that showed this to be the case, added increased validity to the study. However, through triangulating data from TARN, the ONS and
semi-structured interviews, it allowed a rich, robust analysis of the research question to allow a deeper understanding.

A further strength of the study was the use of a comparator region in the analysis of MTC outcomes in Greater London and Greater Manchester. This enabled secular trends to be accounted for, increasing the ability to truly demonstrate the effect of the intervention. The two hospitals studied in South Wales were chosen, not only because of their high level of data ascertainment compared with that expected by HES, but also because they were felt to be comparable in size, structure and baseline quality of care to that provided by the MTCs in the study regions.

Finally, studying the effect of trauma system implementation in two regions of England enabled exploration of advantages and disadvantages of alternative ways of system implementation and system organisation. Through exploring the views of participants and analysing data obtained from two separate regions, this increased the validity of the results. Unlike some previous studies, this study also examined the effect of system implementation on all hospital types within the system and not just MTCs, enabling a broader, population-wide effect to be studied.

One of the principal limitations of the quantitative element of the study was its observational nature, using data entered retrospectively onto the TARN or ONS databases. The use of such methods is unable to prove cause and effect, however, the populations exhibited many similarities and steps were used to minimise bias through the use of a comparator region for one element of the study and calculating the standardised risk adjusted excess rate of survival. As the study only analysed data from two regions of England that implemented trauma systems, rather than the whole country, it may not be possible to generalise the results due to differences in other regional populations (e.g. age structures), transport times and availability of surgical services.

A further limitation related to the fact that following trauma system implementation, MTCs were financially incentivised to report cases to TARN through the Best Practice Tariff,\textsuperscript{17} although TUs
and non-trauma receiving hospitals did not receive this incentive. This perhaps explains the huge increase seen in the number of cases submitted in the year after implementation seen in both Greater Manchester and Greater London in both adults and children and it may account for improvements in process measures such as a reduction in time to CT. This change was not seen to such an extent in South Wales, or indeed, by an increase in the number of deaths that year reported to the ONS. Whilst outcomes and process measures in MTCs were examined in one analysis and the whole system examined in another, no comparison was made of patients treated in different hospital types, such as trauma units and the effect of the BPT on improving quality of care has not specifically been examined in this study.

Finally, the study does not take account of quality of life indices. Using mortality is a very blunt tool when assessing outcomes for trauma patients. However, whilst this data is now routinely collected by TARN to calculate the Glasgow Outcome Score, a five-point disability score ranging from “good recovery” to ‘death”, it was not the case when the study was proposed and initiated. The reporting of such data in 2008-12 was very sporadic in the regions studied and a decision was made not to include this in the study. Also, whilst the provision of rehabilitation care is deemed to be fundamental to an inclusive trauma system and was a key driver of change, availability and use of these services was not examined.

With regards to the qualitative study, participants were limited to senior nurses and doctors who worked within Emergency Departments had been exposed to NHS trauma care provision before, during and after trauma system implementation. The views of patients were not sought at the time due to such a study being implemented by staff at Manchester Royal Infirmary, although this is yet to be published. It was also decided to gain a broad insight into the views of those staff who were delivering trauma care at the ‘front line.’ A number of themes encompassed the role of paramedics and pre-hospital care providers and, in retrospect, it might have been wise to ascertain their views to enable a broader qualitative analysis.

The technique of ‘snowballing’ was used to sample participants. The disadvantage of this non-probability sampling method is there is no guarantee that the sample is representative. It is also
potentially subject to community bias, where the first participants have a strong impact on the rest of the sample. They may have been perceived to be ‘good’ cases with something important to say, or views that matched the initiator. The impact of undertaking qualitative research within a population where I am also a member, could also raise concerns regarding my objectivity, reflexivity and authenticity and result in role confusion where the researcher responds to the participants or analysis of the data from a perspective other than that of researcher. Being close to the area of study could also lead participants to assume that I understood particular issues and prevent them from fully explaining their individual experiences.

Finally, only the views of NHS staff working within a trauma system were explored so the findings may not necessarily be transferable to those staff delivering trauma care outside these systems (e.g. NHS Wales).

**Policy and practice**

This study adds to the body of knowledge around the effect of implementing inclusive trauma systems demonstrating improved patient outcomes and processes of care within two years of implementation. Using South Wales as a comparator, the study has shown that there is room for improvement in this country and adds weight to the argument for introducing a regional trauma system in South Wales by the Welsh Assembly. The research could also be used to support changes to trauma care in other countries of the UK such as Northern Ireland, as well as countries further afield.

Whilst changes to trauma care have taken a long time to come about, it is hoped that the demonstration of improved outcomes will maintain the commitment of the NHS, bodies managing the devolution of health budgets in regions such as Greater Manchester, and those that commission services. Delivering a consultant workforce that can provide a resident 24-hour service to attend to all major trauma patients on arrival at a MTC has huge resource implications for a hospital as does having a CT radiographer on site, a radiologist who can report the images within minutes and enough suitably trained nursing staff to provide safe care
to all patients. Providing excellent trauma care is costly and health-care providers should be adequately compensated for doing so.

Perhaps two groups of trauma patients that warrant particular mention are the elderly and those that die before even reaching hospital. This study, and others, suggest that the trauma population is getting older. As people live longer and more and more become frail, this can be expected. They have particular injury patterns and physiological responses to trauma as well as having different care and rehabilitation needs. Whilst Emergency Medicine has a subspecialty of paediatric EM doctors who have received additional training in treating children, there may well be a similar need for a particular sub-set of doctors in each hospital, MTC or not, who are aware of the intricacies of managing trauma in the elderly and can work with others such as falls teams, rehabilitation specialists and elderly care physicians to optimise their care.

The Royal College of Emergency Medicine could well take a lead on this and work with other specialties, the General Medical Council and Health Education bodies to develop such a training scheme.

The proportion of trauma patients who die outside of hospital is staggering and until we know more about this group of people and their mechanisms of injury there is little that can be done. Whilst limited data is available from the ONS on request, each NHS region should work with other bodies, such as the Police and Coroners officers, to collect and regularly audit such data to highlight areas of concern and to identify where interventions could be targeted. To reduce the number of out of hospital trauma deaths will require a multi-disciplinary approach and may involve changes to Government policy and legislation.

Finally, the study highlights the fact that trauma is a significant public health issue. Trauma care research has historically received significantly less funding from the major UK research councils than other medical conditions such as cancer and stroke. This study demonstrated an enthusiasm on the part of staff to engage in research. Each trauma system should have an academic lead who can foster this enthusiasm, develop and run research studies, either single
centre or through collaboration with others (including the military), and raise the profile of trauma research whilst driving forward improvements in trauma care.

The implications of this study for practice are multiple with some affecting the systems as a whole whilst others affect particular hospital types, regions or clinical roles. Working in a MTC is seen as a marker of prestige by most who work there and is thought to have a positive role in recruitment of the ‘best’ staff. However, retention of (nursing) staff at MTCs was thought to be more and more difficult as workloads increased and staff became ‘burnt-out.’ Many of the TUs and non-trauma receiving hospitals also lost staff to MTCs since the implementation of trauma systems. Whilst this was predominately seen as an issue affecting nursing staff recruitment and retention, there was also a concern from senior emergency medicine doctors that recruiting new consultants to non-MTC hospitals was proving increasingly difficult. Strategies to encourage recruitment and retention of nursing and medical staff at all hospital types within a trauma system should be adopted.

One such strategy could be the rotation of staff to different hospitals within a trauma system. Whilst this has been adopted in some regions through consultants covering ‘trauma’ shifts at MTCs away from their base hospital, it has not been commonplace within nursing. One of the key messages to come out of the qualitative study was that nurses and doctors at TUs and non-trauma receiving hospitals felt de-skilled in managing trauma patients when they (inevitably) presented. Some felt very isolated and far removed from what was going on at the regional MTC. This was particularly the view from ED staff in Greater Manchester where perhaps transport times are longer and more seriously ill patients are seen initially in TUs.

A strategy of rotating staff to MTCs may enhance skills and confidence in managing trauma patients whilst also fostering improved relationships and communication with colleagues working within the same system. It would also present an opportunity to share best practice and raise the quality of care offered to patients overall. An alternative, or additional, strategy to provide support to TUs and non-trauma receiving hospitals would be to establish a team of clinicians who could rapidly attend these hospitals to provide advanced trauma care skills,
stabilise the patient and then rapidly transfer the patient to the most appropriate MTC for definitive care. Whilst such teams are used in paediatric intensive care routinely, their use in trauma care has not been so widespread, although there is evidence from other countries that they can improve survival.25

**Future research**

As previously described, one of the themes coming out of the qualitative analysis was that of the ‘trauma dividend’ and staff in MTCs expressing the view that non-trauma patients also benefitted from improved team-work, quicker access to resources, such as CT scans, and stronger leadership. The effect of such changes could be explored through an observational quantitative study of seriously ill patients, either as a whole, or exploring a sub-group with specific conditions such as stroke or sepsis. These patients would likely also be treated in the resuscitation room. It would also be interesting to explore what happens to a resuscitation room and other patients within it when a trauma patient arrives. As one participant noted, “everyone loves a good trauma” and many expressed the view that a seriously injured patient can bring the ED resuscitation room to a halt. Are non-trauma patients then actually disadvantaged during this time with increased delays to care? A video analysis of staff movements around a resuscitation room may demonstrate if other sick patients are left unsupported whilst staff attend to the trauma patient. This may support the view that trauma patients should be treated in a stand-alone trauma area separate to the ED to avoid disrupting care to others.

Providing trauma care is undoubtedly an expensive undertaking. Indeed, many trauma centres in the United States have closed as they were deemed to be financially unsustainable.39 Consequently, it was surprising to find that a formal cost-effectiveness analysis had not been undertaken before the wide-spread changes to trauma care in England. The role of a cost-effectiveness analysis is to evaluate the cost of providing the new model of trauma care against the old and to measure the health effects to the population. To establish the ‘value’, if any, of making such a change. In the current economic climate in the U.K., financial resources allocated to health-care are limited and should be allocated across interventions and
populations to generate to greatest health benefit. As noted by the World Health Organisation in their guide to cost-effectiveness analysis, "moving resources from cost ineffective interventions to cost effective ones could enhance the efficiency of the health economy." Without a clear understanding of the cost effectiveness of the strategy to implement trauma systems in England, we will never know whether we are maximising the value of our limited resource.

Perhaps one of the most startling findings of this study was the fact that 30-50% of trauma patients die outside of hospital. Whilst large resources are spent optimising hospital delivered trauma care, this large sub-set of patients, affecting mainly younger males, will not benefit as they do not reach hospital or do not reach hospital alive. Further studies are warranted to examine this group in more detail and to ascertain the predominant mechanism of injury, for example. Many of these deaths may be due to deaths on the road from motor vehicle collisions, falls from height or injuries secondary to domestic violence. Further analysis would assist in outlining any areas where injury prevention programmes could be targeted or improvements in pre-hospital care are warranted, to reduce this high level of death.

Leading on from this, to allow thorough analysis of the epidemiology of trauma deaths out of hospital and their causes and to allow interventions to be developed and appropriately targeted, accurate data from multiple organisations, such as the police, ambulance services and pathologists would need to be collected. TARN has been very successful in obtaining and managing data on trauma patients who survive to hospital and I propose that it could establish a sub-set of its database for pre-hospital deaths. Data could be submitted by pathologists or mortuary staff for all such trauma deaths, including mechanism of injury, place of death and the post-mortem report documenting the injuries sustained. This data could then be used by researchers, through TARN, to analyse pre-hospital deaths and monitor trends. Such data could potentially be used by, for example, commercial partners to improve car safety and multi-disciplinary teams to develop and target falls prevention strategies.
Whilst the study has demonstrated overall improvements in the processes of care, it has also demonstrated an improvement in survival for those patients treated within the two trauma systems. Whilst the survival was more marked in those treated in MTCs, there has certainly been improvement across the system as a whole. However, as previously mentioned, mortality is a crude marker of trauma outcome and further research should take into account the effect on patient's quality of life following injury. This data is now routinely being collected by TARN and should feature in further analyses of the effect of implementing trauma systems in England. This study was limited from two years before to two years after trauma system implementation. A number of studies have shown that it is not until 10 years after implementation that the full effects can be demonstrated. Consequently, a further analysis in both of the regions presented here should take place five and ten years on from implementation to establish if improvements in outcomes continue.
Conclusion

There is evidence that inclusive trauma systems improve patient outcome, even though it is a relatively low-quality body of evidence. However, this study supports that view. Improvements in outcome and process measures, seen as markers of quality of care, were seen in both regions studied and NHS emergency department staff also perceived this change. Compared to other studies which showed improvement only after five to ten years, we have seen improvement after a relatively short period of time (two years). Whilst improvement was seen throughout both systems, the changes were most noticeable in MTCs. Whilst an increased proportion of seriously injured patients are now being treated at a MTC and may benefit from improved care, there is still a considerable proportion who are treated, either initially, or totally, outside of these specialist centres.

One of the important messages to come out of this research is that trauma systems have been implemented, not trauma centres. Whilst MTCs have not only benefitted patients, they have also benefitted themselves, whilst other staff at hospitals in the system feel less engaged, concerned about de-skilling and about the future of their hospital without trauma. More needs to be done to foster collaboration and communication across the whole system. Whilst all parties should be confident of delivering high quality trauma care to the populations that they serve they should also appreciate the importance of their own role, and that of their hospital, as important facets of the ‘inclusive’ regional system.

The study also adds to the evidence that the trauma population in England is changing in nature. Whilst once seen as a disease of young men and motor vehicle collisions, more and more elderly patients injured through falls are presenting to trauma services. These patients have their own care needs and systems must ensure that these needs can be met. What is perhaps more striking, is the large proportion, up to 50% of trauma patients, that do not survive to reach hospital alive. Further research is warranted to learn more about this group, their injuries and how strategies can be implemented to reduce this burden. Perhaps some of the greatest future improvements of trauma systems are to be found here.
References


3. Organised trauma systems and designated trauma centres for improving outcomes in injured patients. Mwandri M.; Stewart B.; Hardcastle T.C.; Rubiano A.M.; Gruen R.L. Cochrane Database of Systematic Reviews; Jan 2017; vol. 2017 (no. 1)


32. Metcalfe D.; Costa M.L.; Perry D.C.; Bouamra O.; Lecky F.E.; Woodford M.; Edwards A.; Salim A. Is there a ‘weekend effect’ in major trauma? Emergency Medicine Journal; Dec 2016; vol. 33 (no. 12); p. 836-842

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34. Smith DC, Chapital A, Burgess Uperesa BM, Smith ER, Ho C, Ahana A. Trauma activations and their effects on non-trauma patients. J Emerg Med. 2011:41(1);90-4


Appendices
Appendix 1

Search strategies
Medline 1950 – 2013 Feb week 2
1. Multiple Trauma/ or Trauma Centers/ or trauma systems.mp. or Emergency Medical Services/
2. trauma care.mp.
3. **Outcome Assessment (Health Care)**/
4. exp Death/
5. **Quality of Life**/
6. patient outcome.mp.
7. Injury Severity Score/
8. 3 or 4 or 5 or 6 or 7
9. "trauma system*".m_titl.
10. "trauma cent*".m_titl.
11. trauma system*.ab.
12. trauma cent*.ab.
13. 9 or 10 or 11 or 12
14. 1 or 2
15. 13 and 14
16. 8 and 15
17. limit 16 to humans

EMBASE 1980 to 2013 Feb week 2
1. Multiple Trauma/ or Trauma Centers/ or trauma systems.mp. or Emergency Medical Services/
2. trauma care.mp.
3. **Outcome Assessment (Health Care)**/
4. exp Death/
5. **Quality of Life**/
6. patient outcome.mp.
7. Injury Severity Score/
8. 3 or 4 or 5 or 6 or 7
9. "trauma system*".m_titl.
10. "trauma cent*".m_titl.
11. trauma system*.ab.
12. trauma cent*.ab.
13. 9 or 10 or 11 or 12
14. 1 or 2
15. 13 and 14
16. 8 and 15
17. limit 16 to humans
<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Dates, Location</th>
<th>Data source</th>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
<th>Exposed group</th>
<th>Unexposed group</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mullins, 1998²¹</td>
<td>CBaAS</td>
<td>Oregon, USA. Controlled with Washington, USA, 1985-88 and 1990-93</td>
<td>Oregon Hospital Discharge Index and Washington Department of Social Health Services</td>
<td>Trauma patients aged 16-79 with an ICD-9 coded injury believed to represent major injury</td>
<td>Aged &gt;80</td>
<td>Trauma patients treated in regional hospitals prior to implementation of inclusive trauma system</td>
<td>Trauma patients treated in regional hospitals following the implementation of an inclusive trauma system</td>
<td>Inpatient mortality</td>
</tr>
<tr>
<td>Cameron, 2008²⁰</td>
<td>RCS</td>
<td>Victoria state, Australia, 2001-2006</td>
<td>Victoria State Trauma Registry (VSTR)</td>
<td>All trauma patients with ISS &gt;15 entered onto VSTR</td>
<td>NR</td>
<td>Trauma patients treated within a Victoria state hospital prior to implementation of inclusive trauma system</td>
<td>Trauma patients treated within a Victoria state hospital prior to implementation of inclusive trauma system</td>
<td>Inpatient mortality, Hospital LOS, ICU LOS</td>
</tr>
<tr>
<td>Sampalis, 2009²²</td>
<td>PCS</td>
<td>1993-98, Quebec, Canada</td>
<td>Quebec Trauma Registry and hospital admission records</td>
<td>Trauma patients with one of: ISS &gt;12 Pre-hospital index &gt;3 Two or more injuries with AIS &gt;0-3 Hospital stay &gt;3days</td>
<td>Patients who died at scene</td>
<td>Trauma patients treated at hospitals in Montreal and Quebec City following the implementation of a inclusive trauma system</td>
<td>Trauma patients treated at hospitals in Montreal and Quebec City prior to implementation of a inclusive trauma system</td>
<td>Inpatient mortality</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Dates, Location</td>
<td>Data source</td>
<td>Inclusion criteria</td>
<td>Exclusion criteria</td>
<td>Exposed group</td>
<td>Unexposed group</td>
<td>Outcomes</td>
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<tr>
<td>Twijnstra, 2010</td>
<td>BaAS</td>
<td>1996-98 and 2003-05, Central Region, Netherlands</td>
<td>Dutch National Medical Registration database</td>
<td>Patients who sustained at least 1 injury with an ICD-9 code 800-904 or 910-959</td>
<td>Patients who died before admission</td>
<td>Trauma patients treated in a Central region hospital following the implementation of a regional inclusive trauma system</td>
<td>Trauma patients treated in a Central region hospital before the implementation of a regional trauma system</td>
<td>Inpatient mortality Proportion of patients admitted to a trauma centre</td>
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<tr>
<td>Metcalfe, 2016</td>
<td>BaAS</td>
<td>270 days before and after MTC classification at English MTC's excluding London</td>
<td>TARN HES</td>
<td>TARN inclusion criteria</td>
<td>Isolated hip fractures &gt;65yrs</td>
<td>Those treated at MTC</td>
<td>Those treated at hospitals before MTC designation</td>
<td>Quality of care indices Inpatient mortality Length of stay Functional outcome</td>
</tr>
<tr>
<td>Cole, 2015</td>
<td>PCS</td>
<td>London, UK Feb-April 2013</td>
<td>Hospital and pre-hospital case notes</td>
<td>ISS &gt;15 treated in a Greater London TU or MTC</td>
<td>ISS &lt;16 Non-trauma patient Delay in presentation &gt;72hrs</td>
<td>Trauma patient treated in Greater London TU or MTC post system implementation</td>
<td>Trauma patient evaluated as part of NCEPOD review 2007 (pre-trauma system implementation)</td>
<td>Quality of care (NCEPOD) Inpatient mortality</td>
</tr>
<tr>
<td>Claridge(^{32}) 2013</td>
<td>BaAS</td>
<td>North Ohio, USA 2008-2011</td>
<td>Regional trauma database</td>
<td>Trauma activation or admission</td>
<td>Late effects of injury Superficial injuries</td>
<td>Treated in a trauma system hospital post implementation</td>
<td>Treated in a pre-trauma system hospital</td>
<td>Inpatient mortality</td>
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<tr>
<td>Mchee(^{33}) 2015</td>
<td>BaAS</td>
<td>Alberta, Canada 2002-07, 2008-11</td>
<td>Alberta trauma registry</td>
<td>&gt;16 years Trauma patients</td>
<td>Those missing data (e.g. BP/age/ISS)</td>
<td>Treated in inclusive trauma system with bypass</td>
<td>Treated in exclusive system</td>
<td>Inpatient mortality Length of stay Number of surgical interventions</td>
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</tbody>
</table>
### Appendix 3: Characteristics of excluded studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Dates, Location</th>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
<th>Exposed group</th>
<th>Unexposed group</th>
<th>Outcomes</th>
<th>Reason for ineligibility</th>
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</thead>
<tbody>
<tr>
<td>Curtis, 2012</td>
<td>Longitudinal service evaluation</td>
<td>2003-07, New South Wales, Australia</td>
<td>Trauma patients with; ISS &gt;15 Aged &gt;15</td>
<td>NR</td>
<td>Trauma patients treated at one of 8 level I trauma centres</td>
<td>Trauma patients treated at one of 3 regional trauma centres</td>
<td>Inpatient mortality Hospital LOS ICU LOS</td>
<td>Examines trends over time following the implementation of trauma centres rather than inclusive system No bypass or inter-hospital transfer agreements in place during study High risk of bias (no adjustment for confounding)</td>
</tr>
<tr>
<td>Daniel, 2010</td>
<td>RCS</td>
<td>1997-2002 and 2003-08, Texas, USA</td>
<td>All trauma patients entered onto local trauma database</td>
<td>Hip fractures in those over 65 yrs</td>
<td>Trauma patients treated in a level III TC following the implementation of a full time trauma service</td>
<td>Trauma patients treated in a hospital prior to the implementation of a full time trauma service</td>
<td>Inpatient mortality Hospital LOS ICU LOS</td>
<td>Single centre study examines change in process rather than at system level. Centre was designated a TC in 1999,</td>
</tr>
<tr>
<td>Study</td>
<td>Institution</td>
<td>Time Period</td>
<td>Database/Inclusion Criteria</td>
<td>Exclusion Criteria</td>
<td>Outcomes</td>
<td>Comments</td>
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<td>Durham, 2006&lt;sup&gt;96&lt;/sup&gt;</td>
<td>RCS</td>
<td>2001-03, Florida, USA</td>
<td>All trauma patients on Florida Agency for Health Care Administration database with ICD-9 codes 800-959</td>
<td>Those aged &gt;65yrs with femoral neck fractures post fall, Patients with single injury that had no potential for mortality, Admissions not classified as emergency, Patients with diagnoses relating to insertion of foreign objects, Complications from previous trauma, Transfers from another acute care hospital, LOS &lt;24hrs</td>
<td>Trauma patients treated at a trauma centre, Trauma patients treated at a non-trauma centre, Inpatient mortality, Cost/life year saved</td>
<td>Excluded those aged &gt;65 from mortality analysis, Excluded transfers to and from other hospitals, Excluded patients who were discharged to other facilities eg. hospice, rehab centre, local hospital, No ISS coding, High risk of bias – used non validated methodology for trauma patients</td>
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<tr>
<td>Study</td>
<td>Year</td>
<td>Region</td>
<td>Patients Discharged</td>
<td>Details</td>
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<tr>
<td>Gabe, 2012</td>
<td>RCS</td>
<td>2006-09, Victoria, Australia</td>
<td>All adult (&gt;18yr) blunt trauma patients with a ISS &gt;15</td>
<td>Treated within an inclusive trauma system early in its development</td>
<td>NR</td>
<td>Treated within an inclusive trauma system later in its development</td>
<td>Inpatient mortality</td>
<td>Glasgow Outcome Scale - Extended</td>
</tr>
<tr>
<td>Gabe, 2012</td>
<td>PCS</td>
<td>1997-2001 North Iraq and Cambodia</td>
<td>All trauma patients</td>
<td>Cases with insufficient data for severity scoring and outcome assessment</td>
<td>Trauma patients treated by local health workers who had been trained in advanced trauma life support skills</td>
<td>Trauma patients treated by local health workers before they received formal training in advanced life support skills</td>
<td>Effect of treatment on pre-hospital physiologic severity levels</td>
<td>Trauma mortality</td>
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to penetrating injury, long pre-hospital transport times

The North Iraq system also managed emergency medical patients? included in study

<table>
<thead>
<tr>
<th>Study</th>
<th>Hospital</th>
<th>Dates</th>
<th>Inclusion Criteria</th>
<th>Exclusion Criteria</th>
<th>Outcomes</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kane, 1992&lt;sup&gt;39&lt;/sup&gt;</td>
<td>RCS</td>
<td>Sept-Nov 1982 and Sept-Nov 1984, Los Angeles state, USA</td>
<td>Injured &lt;48hrs before ED admission</td>
<td>ISS &gt;15 Admitted to or died at an acute care hospital Had care provided by one of the 57 hospitals participating in study Had a hospital chart that was able to be located</td>
<td>Treated in a hospital following its verification as a trauma centre</td>
<td>Treated in a hospital prior to its verification as a trauma centre</td>
</tr>
<tr>
<td>Study (Year)</td>
<td>Type of Study</td>
<td>Time Period</td>
<td>Inclusion Criteria</td>
<td>Outcome Measures</td>
<td>Exclusion Criteria</td>
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<tr>
<td>Leung, 2011</td>
<td>Longitudinal study of service evaluation</td>
<td>2004-08, Hong Kong</td>
<td>Inclusion in regional trauma registry (inclusion criteria not given)</td>
<td>Treatment at one of five designated trauma centres</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Mann, 2001</td>
<td>RCS</td>
<td>1985-87 and 1990-94, Oregan, USA</td>
<td>Age &gt;80, One or more “index injury” upon ED arrival</td>
<td>Died within 30 minutes of arrival in ED</td>
<td>Treated at rural/remote hospital 3 years after trauma centre verification</td>
<td></td>
</tr>
<tr>
<td>Moore, 2010</td>
<td>Longitudinal study of service evaluation</td>
<td>1999-2006, Quebec, Canada</td>
<td>All trauma patients with injuries meeting ICD-9 codes 800-959 plus: Death following injury ICU admission Hospital LOS &gt;2d Transfer in Complications Burns Late effects Foreign bodies Patients dead on arrival Patients who delayed consultation for &gt;48hrs Isolated hip fractures</td>
<td>Trauma patients treated within the inclusive TS later after its implementation</td>
<td>Trauma patients treated within the inclusive TS early after its implementation</td>
<td></td>
</tr>
</tbody>
</table>

**Leung, 2011**: Inclusion in regional trauma registry (inclusion criteria not given) NR

**Mann, 2001**: Age >80, One or more “index injury” upon ED arrival Died within 30 minutes of arrival in ED

**Moore, 2010**: All trauma patients with injuries meeting ICD-9 codes 800-959 plus: Death following injury ICU admission Hospital LOS >2d Transfer in Complications Burns Late effects Foreign bodies Patients dead on arrival Patients who delayed consultation for >48hrs Isolated hip fractures

**Inpatient mortality**

**Hospital LOS**

**ICU LOS**

**Exclusive system** Longitudinal study of trauma centre performance

**Excluded those over 80yrs**

**Excluded ED deaths** Only certain ICD codes included

**Excluded specific injuries**

**All data collected whilst TS operational. Examined effects of maturation of TS on outcome. No control group**
<p>| Mullins, 1996&lt;sup&gt;33&lt;/sup&gt; | RCS | 1985-87 and 1991-93, Oregon, USA | Trauma patients featuring on hospital administrative database with specific ICD-9 injury codes relating to chest, pelvic, spleen/liver, femur/tibia and head injury | Excluded deaths in the ED or prior to reaching hospital | Trauma patients treated in state hospitals following implementation of an inclusive trauma system | Trauma patients treated in state hospitals after the implementation of a state wide trauma system | Risk adjusted odds ratio of admission and of death | Included injuries of all severity (No ISS) | Excluded patients who died in the ED | Only included certain injury codes | No physiological data available or confounded for | Administrative data used to predict AIS and ISS codes – not validated | Duplication with other Mullins paper |
| Mullins, 2004&lt;sup&gt;44&lt;/sup&gt; | RCS | 1984-85 and 1986-87, Oregon, USA | Trauma patients included on administrative database and having ICD-9 code 800-959 | Patients with injury codes 905 (late effects of injury), 930-39 (foreign bodies), 958 (trauma complications) | Trauma patients treated in state hospitals following the implementation of a inclusive trauma system | Trauma patients treated in state hospitals prior to implementation of inclusive trauma system | Inpatient mortality | Duplication with other Mullins paper | Administrative data used to predict AIS and ISS codes – not validated |</p>
<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Timeframe, Location</th>
<th>Patients</th>
<th>Deaths caused by:</th>
<th>Trauma patients treated in a state with a trauma system</th>
<th>Trauma patients treated in a state without a trauma system</th>
<th>Ratio of mortality rates in states with a trauma system compared to states without (Incidence Rate Ratio - IRR)</th>
<th>Study makes assumption that all state trauma systems are equal and at same level of maturity</th>
<th>High risk of bias (no adjustment for confounding)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nathens, 2000&lt;sup&gt;25&lt;/sup&gt;</td>
<td>Cross-sectional database study</td>
<td>1995, Multiple states, USA</td>
<td>All patients who died from ICD-9 coded injuries E810-829, 846-848, 831, 880-888, 916-922, 960, 965-966, 968 and featured on National Centre for Health Statistics database or Fatality Analysis Reporting System</td>
<td>Burns, Suicide, Intentional injury, Submersion, Poisoning</td>
<td></td>
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<td></td>
<td>Study makes assumption that all state trauma systems are equal and at same level of maturity</td>
<td>High risk of bias (no adjustment for confounding)</td>
</tr>
<tr>
<td>Nicholl, 1997&lt;sup&gt;25&lt;/sup&gt;</td>
<td>CBAS</td>
<td>1990-93, North West Midlands, United Kingdom. Two control regions of Lancashire and Humberside</td>
<td>All trauma patients with ISS &gt;15 and brought to ED by any means other than by ambulance services from outside the regional systems</td>
<td>NR</td>
<td>Treated in regional ED’s following the implementation of a trauma system</td>
<td>Treated in regional ED’s prior to the implementation of a trauma system</td>
<td>Survival rates standardized for age, injury severity and revised trauma score at 6 months following trauma</td>
<td>Main investment and process changes implemented at single trauma centre</td>
<td>No formal bypass/inter-hospital</td>
</tr>
</tbody>
</table>
| Nirula, 2006<sup>46</sup> | RCS | 1994-2001 67 hospitals in 27 states in the USA | Trauma patients aged 18+ within the US National Trauma Data Bank | NR | Treated in a Level I or II trauma centre | Treated in a Level III, IV or undesignated centre | Modified Functional Independence Measure | Changes to processes of care, transfer agreements
Functioned as an exclusive system with little input from regional hospitals
Evaluation was made soon after changes were made – other studies have shown that trauma centre/system maturation takes years to show benefit | Very high risk of bias. (FIM has not been
<table>
<thead>
<tr>
<th>Reference</th>
<th>Journal</th>
<th>Year Range</th>
<th>Location</th>
<th>Study Design</th>
<th>Outcome</th>
<th>Comments</th>
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<td>Peleg, 2004&lt;sup&gt;47&lt;/sup&gt;</td>
<td>RCS</td>
<td>1997-2001, Israel</td>
<td>All trauma patients with ISS &gt;16 and had injury coded ICD-9 800-959</td>
<td>Dead on arrival/Discharged following treatment in ED</td>
<td>Trauma patients treated at one of six level I trauma centres</td>
<td>Inpatient mortality</td>
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<tr>
<td>Reilly, 2004&lt;sup&gt;48&lt;/sup&gt;</td>
<td>RCS</td>
<td>1998-2000 New York, USA</td>
<td>Trauma patients admitted to New York hospitals that submitted data to the</td>
<td>Transfers Burns</td>
<td>Admitted to trauma centres</td>
<td>Admitted to non-trauma centres</td>
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| Sampalis, 1995<sup>59</sup> | RCS | 1987 and 1993. Quebec, Canada | Statewide Planning and Cooperative Research System | Transport to hospital by ambulance | Admission for treatment of injuries | NR | Treated at one of 2 Montreal hospitals post level I verification | Treated at one of 3 Montreal hospitals providing trauma care | Inpatient mortality | Did not take account of patients who died in ED
Study evaluates effect of trauma centre verification on outcome at 2 city hospitals.
Exclusive system – no pre-hospital bypass protocols |

| Sethi, 2007<sup>50</sup> | PCS | 2000-01, Malaysia | Age >12
Injury and: ICU admission
Admission <72hrs
Dead in hospital | Patients undergoing secondary transfer
Dead on ED presentation | Patients directly admitted to a central tertiary care hospital | Patients directly admitted to a district general hospital | Inpatient mortality
Discharge Barthel Index | Exposed group does not include secondary transfers
No bypass protocols or triage at scene – patients transported to |
<table>
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<th>Study</th>
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<th>Country</th>
<th>Study Population</th>
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<th>LOS</th>
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<th>Comparison Notes</th>
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<td>Spijkers, 2010</td>
<td>RCS</td>
<td>1996-98 and 2003-05, Utrecht, Netherlands</td>
<td>All trauma patients aged 18+ Aged &lt;18 Drowning Transfers</td>
<td>Treated at single hospital after TC designation</td>
<td>Treated at single hospital before TC designation</td>
<td>Despite implementing a inclusive regional system, the paper solely compared outcomes before and after TC designation at a single hospital.</td>
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<td>Sturms, 2006</td>
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<td>Trauma patients with ISS &gt;15 who are: Transferred to or from hospital Die from their injuries Treated in the ED and are admitted</td>
<td>Major trauma patients treated within an inclusive trauma system</td>
<td>Major trauma patients included in UK and US trauma registries (TARN and NTDB)</td>
<td>Does not compare pre and post system implementation on the same population. Many hospitals submitting data to UK/US trauma registries not comparable</td>
<td></td>
</tr>
<tr>
<td>Tinkoff, 2009</td>
<td>RCS</td>
<td>1998-2007 Delaware, USA</td>
<td>All ages All trauma patients that Patients over 55yr with solitary fractured NOF, Patients receiving treatment at any hospital</td>
<td>Comparison was made to the National</td>
<td>Inpatient mortality</td>
<td>Control group is not standardised (eg. mix of</td>
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<tr>
<td>Utter, 2006&lt;sup&gt;st&lt;/sup&gt;</td>
<td>RCS</td>
<td>2001, Multiple states, USA</td>
<td>Trauma patients with at least 1 ICD-9 code 800-959 and ISS &gt;15</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Trauma patients with ICD-9 codes consistent with foreign bodies, burns, late effects of injuries, early complications secondary to injury</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Patients aged &lt;15</td>
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<td>Trauma patients treated in most 'inclusive' trauma systems</td>
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<td>Inpatient mortality</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Rate of triage to regional trauma centre</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Study compared trauma system level of inclusiveness with outcome</td>
<td></td>
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</table>

'Inclusiveness' of a state system was defined by the proportion of hospitals within a state that are designated.
No account made of bypass/transfer protocols

Assumption that all systems are at the same level of maturity and that all hospitals verified at a particular level are equal

High risk of bias (eg. no adjustment of confounding for physiological differences in injury severity)
Appendix 4

Search strategy: Medline - 1946 to present, EMBASE - Excerpta Medica Database 1974 to present.

"(exp "OUTCOME ASSESSMENT (HEALTH CARE)"/ OR exp DEATH/ OR exp "QUALITY OF LIFE"/ OR exp "INJURY SEVERITY SCORE"/ OR ("patient outcome**").ti,ab) AND ((("trauma system**").ti,ab OR ("trauma cent**").ti,ab) AND (("trauma care").ti,ab OR (exp "MULTIPLE TRAUMA"/ OR exp "TRAUMA CENTERS"/ OR exp "EMERGENCY MEDICAL SERVICES"/)))"

LIMITS: dates 2013 to 2018, human

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Appendix 5

PRISMA flowchart describing updated systematic review study selection (2013-2018)
Appendix 6

London Ambulance Service Major Trauma Decision tree (for adults)

Reference: London Trauma Office. Adapted for local use by SECAmb and South West London Trauma Network
Appendix 7

London Major Trauma Decision Tool (Adults & Children 12-18 Years Old)

**Step 1**
Assess vital signs and level of consciousness
- AA: Glasgow Coma Score of 13 or below
- BB: Systolic blood pressure less than 90 mmHg
- CC: Respiratory rate less than 10 or greater than 23 bpm

**Step 2**
Assess anatomy of injury
- AA: Amputations or cut injury with open physiology
- BB: Penetrating trauma below the neck above the knee (involving arms)
- CC: Suspected open and/or depressed skull fracture
- DD: Suspected pelvic fracture
- EE: Spinal trauma suggested by abnormal neurology
- FF: Open fracture of the lower limb proximal to the ankle
- GG: Barricaded greater than 30 percent
- HH: Facial burns with complete loss of lower half of face
- II: Circumferential burns from a flame injury

**Step 3**
Assess mechanism of injury
- AA: Traumatic death in same passenger compartment
- BB: Falls 30 ft (been stamped)
- CC: Person trapped under vehicle or large object (including 'one under')
- DD: Hail to the windscreen and/or damage to the 'W' post of the vehicle caused by impact of individual outside of the vehicle

**Step 4**
Assess special patient consideration
- AA: Elderly patient (65 or over)
- BB: Pregnant (20-32 weeks)
- CC: Known to have bleeding disorder or receiving current anti-coagulation therapy
- DD: Sepsis or novel oral anticoagulant agent
- EE: Mentally obese

**Step 5**
Assess system consideration
- AA: Significant over concern only when discussed with a Trauma Paramedic within 60 min

London Ambulance Service Major Trauma Decision Tool
London Ambulance Service Trauma Decision Tool for Children
Appendix 9

Greater Manchester Major Trauma Network – Adult Pathway

North West Ambulance Service Pathfinder (triage) tool (for adults)
Dear Colleague,

Exploring the views of NHS staff involved in implementing trauma systems in two English regions

As a member of NHS staff who has experience of working within or implementing a trauma system, I would like to invite you to take part in a research study about trauma systems. This qualitative study will allow me to obtain valuable information from NHS staff about their experiences of being involved in the introduction of a trauma system.

I have attached an information sheet about this study together with a study reply form. If after reading this information you are happy to take part in the study please sign the reply form and either return by post or email. If after reading this information you would prefer not to take part please tick the relevant section of the reply form and return by post or email.

If you would like to talk to me about the study I can telephone you to discuss taking part and to answer any questions that you might have about the study. If you would like me to contact you by telephone please complete, sign and return the appropriate sections of the reply form. Once I have received your form, I will telephone you to spend a few minutes discussing the study and taking part.

Yours faithfully,

Dr Matt Davies
College of Emergency Medicine Doctoral Research Fellow
matt.davies@manchester.ac.uk
STUDY INFORMATION SHEET

1. Study title

Exploring the views of NHS staff involved in implementing trauma systems in two English regions.

2. Invitation

As a member of NHS staff either involved in the implementation of, or working within, a regional trauma system I would be very interested to learn more about your experiences.

This is to ask you if you would be willing to take part in this research project. Before you decide it is important for you to understand why we are asking NHS staff these questions and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

3. What is the purpose of the study?

I am undertaking a PhD studying the effectiveness of implementing trauma systems in England. The will consist of a number of elements including this study of staff experiences. I am therefore attempting to understand the views, challenges and any issues you may have experienced during the implementation of the trauma system.

4. Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

5. What will happen to me if I take part?

I will invite you at a time and place convenient for you, to take part in an interview to ask you for your views about the implementation of the regional trauma system. I would expect the interview to take around 60-90 minutes. This interview will take place face to face at a place convenient to you. The interview will be conducted by Dr Matt Davies who is a PhD student at the University of Manchester. I will ask for your permission to audio-record the interview and you will have the opportunity to decline recording the interview in which case I will write down your answers to the questions asked.
6. **What are the risks or benefits of taking part?**

I do not think there are any risks for you in taking part in an interview. I hope the interview may benefit you by encouraging reflection on this important subject.

7. **Will my taking part in this study be kept confidential?**

Yes. Your name will not be written on any of the information you give us, only a code number. None of the information you give will ever be linked with your name. The recording will be encrypted and destroyed after it has been finished with.

8. **What will happen to the results of the research study?**

The results will be summarised and presented both at medical conferences and through scientific publications in medical/nursing journals, so health professionals can learn more about the results of our research. At the end of the study you will be provided with a copy of the findings if you would like to receive this. You will not be identified in any report/publication.

Data will be collected, stored, analysed and disposed of in accordance with the regulations of the University of Manchester and the Data Protection Act 1988. Data will be stored in an encrypted format and at all times will remain anonymous. Research governance best practice will be followed as detailed by the Medical Research Council.

9. **Who is organising and funding the research?**

Dr Davies is the lead researcher for this study and is supervised by Professor Chris Todd (University of Manchester) and Professor Fiona Lecky (University of Sheffield). His PhD is funded by the Royal College of Emergency Medicine and the Trauma Audit and Research Network.

10. **What should I do now?**

I have enclosed a brief reply form which you may either post back to me or you may simply email a reply as instructed on the reply form to the email address provided. Your reply will let me know whether or not you wish to take part in an interview, or whether you would like more information about it. It is entirely up to you whether you take part.

11. **Contact for further Information**

You may obtain more information about this study by contacting Dr Matt Davies at the address given below.

12. **What if I want to withdraw from the study?**

You can withdraw from this additional study at any point and there will be no further contact with you. If you have already participated in an interview and you would
subsequently prefer to withdraw the answers that you have given during the interview will be destroyed and will not be included in our results and reports assuming they have not already been included in our analysis and reporting activities by that stage. I will be preparing the results for report during the summer months of 2015.

14. What if there is a problem?

Complaints
If you have a concern about any aspect of this study, you should ask to speak to Dr Matt Davies will do his best to answer your questions or Professor Chris Todd (chris.todd@manchester.ac.uk). If they are unable to resolve your concern or you wish to make a complaint regarding this study, please contact the University of Manchester Research Practice and Governance Co-ordinator on 0161 2757583 or 0161 2758093 or by email to:

research-governance@manchester.ac.uk.

This study is organised by Dr Matt Davies, College of Emergency Medicine Doctoral Research Fellow, Trauma Audit and Research Network, University of Manchester, Mayo Building, Salford Royal NHS trust, Stott Lane, Salford. M6 5PR.

Telephone: 07760442937
Email: matt.davies@manchester.ac.uk

Thank you for taking the time to read this information leaflet.

Thank you for reading this information. You will be given a copy to keep. If you decide to participate you will also be given a signed consent form.
STUDY REPLY FORM

Project Title: Exploring the views of NHS staff involved in implementing trauma systems in two English regions

Please complete, sign and date and return it to Dr Matt Davies, Trauma Audit + Research Network, Mayo Building, Salford Royal Hospital, Eccles New Road, Salford. M6 8HD
OR: Please complete the form and email this document to matt.davies@manchester.ac.uk

Your name: .............................................................................................................

NHS organisation: ..................................................................................................

Address: .................................................................................................................

The best phone number to use to contact you:....................................................

Your email address: ............................................................................................... 

Please put a cross (x) next to any that apply:

☐ I would like to take part in this study and am willing to be contacted about taking part if I am selected

☐ I would like to be contacted so I can ask further questions about the study and receive more information

Signature (not required if returning the reply form via email):

..............................................................................................................................

Date ..................................................
Appendix 12

Participant Identification Number:

CONSENT FORM (v1, 5th June 2013)

Title of Project: Exploring the views of NHS staff involved in implementing trauma systems in two English regions

Lead Researcher: Dr Matt Davies. Specialist Registrar and Doctoral Research Fellow in Emergency Medicine

Please initial box

1. I confirm that I have read and understand the information sheet dated June 2013 (version 1) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected.

3. I give my consent for the interview to be audio-recorded.

4. I agree to take part in the above study.

_________________________ __/__/____ ______________________________
Name Date Signature

_________________________ __/__/____ ______________________________
Name of person taking consent Date Signature (if different from researcher)

_________________________ __/__/____ ______________________________
Researcher Date Signature

When completed: 1 for participant; 1 for researcher site file
Appendix 13

Topic guide

Participant ID:

Objectives

- To describe the explanations underlying trauma system implementation
- To describe the reasons for a particular model being implemented and how it was chosen
- To describe the facilitators required to enable change
- To describe the barriers to implementation
- To describe the elements of a trauma system that are perceived to improve effectiveness
- To describe clinicians’ experiences of their involvement in a trauma system

Introduction (read to participant)

Welcome. Thank you for agreeing to be interviewed as part of this study that will assess the effectiveness of implementing trauma systems in two regions of England. My name is Matt Davies and I am a Specialty Registrar in Emergency Medicine and also studying for a PhD at the University of Manchester. This study will form part of my doctorate and I am funded partly by the College of Emergency Medicine and partly by the Trauma Audit and Research Network.

Over the next 60 minutes or so I would like to ask you a number of questions exploring your background, your role within the trauma system and your views on the implementation, organisation and future of the system. There are no right or wrong answers and everything that you say will be treated confidentially.

With your permission, I will audio record the interview to allow me to transcribe it later on. The recording will be encrypted and disposed of once transcribed. At no point will comments that you make today be able to be ascribed back to you in any published documents that may follow this study.
The study will comply with the data protection regulations stipulated by the University of Manchester in accordance with the Data Protection Act 1988. You are free to stop the interview at any point or to refrain from answering particular questions.

Please let me know if you would like to stop the interview for a break. If, at 60 minutes the interview has not finished, I will stop the interview to ask your consent to continue.

Do you have any questions?

Could I now ask that you consent verbally to being interviewed today and to the interview being audio-recorded?

**Topic 1: Background**

As a background, could you tell me a little about you?

- Age
- Relationship and family status
- Brief career history
  - Worked within a trauma system before eg. abroad
  - Experience and interest in trauma
- Current role
  - Time in role
  - Full/part-time

How would you define the term ‘trauma system?’

**Topic 2: Before system implementation**

When you first heard that a trauma system was to be introduced in the region, what did you think about that?

Need for change

- Quality of care
- Delays in treatment
• Preventable deaths / poor outcomes

Local department
• Closure/expansion
• Resource implications
  Change in patient numbers
• Ability to cope

Personal effect
• Change in job role
• Change in working hours
• Own clinical skills/abilities

Topic 3: During system implementation
Could you describe how the system was introduced in this hospital.
Did it all go smoothly?

Barriers
• Time
• Communication
• Individuals
• Resources
  o Equipment
  o Staffing
  o Funding

Facilitators
• Individuals
• National and local strategy
• Funding
• Teamwork
What effect has the change had on you personally?

- Family life
- Career
- Clinical skills

What effect has it had on your department?

- Patient numbers
- Severity of injuries seen
- Time spent with patients
- Effect on non-trauma patients
- Recruitment/loss of staff
- Communication and teamwork with others
  - Within department
  - With other specialties

**Topic 4: Processes of care**

Can you think of an example of a trauma patient that you cared for recently and how their care was different now to what would have been offered before the system was introduced?

Pre-hospital

- Bypass protocols
- Rapid access to definitive care

Hospital

- Consultant led trauma teams
- Treatment protocols eg. massive transfusion
- Time to CT
- Time to surgery
Rehabilitation

- Access
- Commitment

System wide

- Education and training
- Communication within and between teams
- Clinical governance
  - Audit
  - System management

Do you think that the trauma system has changed patient outcomes? Why?

**Topic 5: The future**

How do you see the future for the system?

**Sustainability**

- Change to structure
  - Moving services
  - Change in number of MTC’s

**Working practices**

- 24/7 consultant presence
- Staff levels
- Retaining skills of ED staff not exposed to trauma

As we finish this interview, on reflection of your experiences with this trauma system, what advice would you give to someone implementing a trauma system in a region currently without?
**Conclusion** (read to participant)

Many thanks for your time today. Are there any other points that you would like to raise that were not covered during the structured interview?

I would like to reiterate that your comments will be treated confidentially and will remain anonymous. Once all of the interviews have taken place and the data analysed, I hope to publish the findings in a peer-reviewed journal. The study will also form part of my PhD thesis. I would be happy to provide you with a copy of the study report in due course, if you wish.