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An Evaluation of a Trauma Unit Bypass Tool in Predicting Major Trauma

by

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Thesis for the degree of Doctorate in Clinical Practice

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Abstract

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Introduction In order to direct patients to specialist Major Trauma Centres (MTCs), triage is performed at the scene of an incident to evaluate the extent of a patient's injuries. The most severely injured patients are then transported directly to an MTC, even if there is a closer Emergency Department (ED). This process is known as 'Trauma Unit Bypass' (TUB) and decision support tools are provided for use by ambulance service providers. This study aims to evaluate a tool in current operational use and suggest amendments which may improve its performance in clinical practice.

Methods This study used data from a period of 12-months (1065 cases) to evaluate the performance of a TUB tool used in an English ambulance service. Data were sourced from the Trauma Audit and Research Network (TARN) and ED records and case reviews were performed to extract the required information. Statistical analysis was performed to evaluate the accuracy of the tool in identifying major trauma, defined as an Injury Severity Score (ISS) greater than 15. Further analysis was undertaken to make recommendations for alterations to the tool.

Results The sensitivity of the Wessex TUB is 51.3% and the specificity is 71.3% which makes the tool a poor predictor of major trauma. The tool could be improved by altering thresholds for vital signs (blood pressure and Glasgow Coma Scale) and by providing clarity around the injury findings.

Conclusion This study provides the first full evaluation of this tool in clinical practice and makes some recommendations to improve performance. This could lead to more accurate identification of patients who have suffered major trauma and ensure they are transported to an appropriate specialist centre. However, it was identified that ISS>15 may not be the most useful outcome measure and it is recommended that a new definition is developed which more accurately describes need for MTC input.

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Research Thesis: Declaration of Authorship

Print name: Eleanor S. Freshwater

Title of thesis: Evaluation of a Trauma Unit Bypass Tool in Predicting Major Trauma

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

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2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
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6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
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Definitions and Abbreviations

ACS-COT	American College of Surgery – Committee on Trauma
AHP	Allied Health Professional
AIS	Abbreviated Injury Score
AOC	Area Under the Curve
APACHE II	Acute Physiology And Chronic Health Evaluation II
BP	Blood Pressure
BPT	Best Practice Tariff
CoP	College of Paramedics
DOR	Diagnostic Odds Ratio
EMS	Emergency Medical Service
GAP	Glasgow coma scale, Age and systolic blood Pressure
GCS	Glasgow Coma Score
HR	Heart Rate
HRA	Health Research Authority
ICU	Intensive Care Unit
ITU	Intensive Treatment Unit
LR	Likelihood Ratio
MATTS	Major Trauma Triage Study
MCA	Mental Capacity Act
MOI	Mechanism of Injury
MTC	Major Trauma Centre
NFTI	Need for Trauma Intervention
NTS	New Trauma Score
NPV	Negative Predictive Value
OR	Odds Ratio
PHEA	Pre Hospital Emergency Anaesthesia
PPV	Positive Predictive Value
ROC	Receiver Operator Curve
RR	Respiratory Rate
SCAS	South Central Ambulance Service

Sn ..... Sensitivity

Sp ..... Specificity

SPO_2..... Oxygen Saturation

SWASFT..... South Western Ambulance Service Foundation Trust

TBI..... Traumatic Brain Injury

TCN ..... Trauma Centre Need

TRISS ..... Trauma and Injury Severity Score

T-RTS ..... Triage Revised Trauma Score

TT ..... Trauma Triage

TTA..... Trauma Team Activation

TU..... Trauma Unit

TUB ..... Trauma Unit Bypass

UHS..... University Hospital Southampton

WTN ..... Wessex Trauma Network

Chapter 1 Introduction

1.1 Introduction

In order to direct patients to specialist Major Trauma Centres (MTCs), triage is performed at the scene of an incident to evaluate the extent of a patient's injuries. The most severely injured patients are then transported directly to an MTC, even if there is a closer Emergency Department (ED). This process is known as 'Trauma Unit Bypass' (TUB) and decision support tools are provided for use by ambulance service providers. This study aims to evaluate a tool in current operational use and suggest amendments which may improve its performance in clinical practice.

Understanding the effectiveness of a decision-support tool is important in clinical practice, particularly if it is used as a protocol rather than a guideline as this implies clinician compliance is required. Having evaluated the current TUB tool, the study further analyses various anatomical and physiological variables to improve its accuracy and makes suggested modifications.

This chapter sets out the extent of the disease of major trauma, organisation of systems both in this country and internationally to manage patients following major trauma, and how patients are directed to regionally delivered specialist services when required. A brief description of pre-hospital emergency care in the UK, including the paramedic workforce, then follows. Finally, the chapter sets out the aims and objectives of the study and discusses the context within which the research has taken place.

1.2 Major trauma and trauma networks

Each year, 4.4 million people worldwide die from injuries sustained by trauma, with 3.16 million of these being caused unintentionally. Violence, including suicide, homicide, and war and conflict account for the remaining numbers. Roughly 1 in 3 deaths result from road traffic crashes (World Health Organization, 2021). In the UK, around 16,000 people per year die as a result of trauma (TARN, 2021b). Although traditionally seen as a disease of the young, the demographic pattern of major trauma patients is changing with falls in the elderly population becoming increasingly significant (Kehoe et al., 2015, Moran et al., 2018).

Evidence demonstrates that the organisation of trauma care into regional systems improves outcomes and reduces preventable death (Davenport et al., 2010). Early results from England showed positive results since re-configuration (Davenport et al., 2010, Dixon, 2014) and this has continued as the networks have developed and matured (Moran et al., 2018). This centralisation of services ensures that patients can be cared for in units where all of the specialties required are located on one site and the resultant increased volume of trauma should lead to increased skill and expertise. However, it should be recognised that there are additional elements which must be studied, and processes implemented to gain the maximum benefit from this change in configuration (Davenport et al., 2010). These may include processes and guidelines, for example automatic acceptance criteria of secondary transfers from other hospitals (Dickinson and Eynon, 2014) and holistic care delivered on a dedicated trauma ward (NICE, 2016c).

Trauma networks were introduced to England in 2012 in response to reports that the care delivered to victims of trauma was suboptimal (Copas and Moran, 2014). Lecky (2002) identified large variations in care delivered to patients whom had been severely injured. A National Confidential Enquiry into Patient Outcome and Death (NCEPOD, 2007) reported that

> *“almost 60% of the patients in this study received a standard of care that was less than good practice. Deficiencies in both organisational and clinical aspects of care occurred frequently.”*

The National Audit Office (2010) went even further in describing the situation, stating

> **"***Current services for people who suffer major trauma are not good enough. There is unacceptable variation, which means that if you are unlucky enough to have an accident at night or at the weekend, in many areas you are likely to receive worse quality of care and are more likely to die. The Department of Health and the NHS must get a grip on coordinating services through trauma networks, on costs and on information on major trauma care, if they are to prevent unnecessary deaths.***"**

Interestingly, this paper also identified costs to the nation of major trauma, not only in the delivery of care but the economic output lost through death and disability. In other words, it is in the country’s interest to care for and rehabilitate people to

return them to tax paying status following serious injury. Trauma is the leading cause of death among children and young adults aged under 44, with 16,000 people dying per year in England and Wales (TARN, 2018).

English Major Trauma Centres (MTCs) were designated by the Department of Health, following an assessment of clinical capabilities and requirements of the population (Metcalfe et al., 2016). Trauma networks operate a 'hub and spoke' model with specialist MTCs supported by Trauma Units (TUs) and Local Emergency Hospitals (LEHs). Trauma Units (TUs) are equipped to deal with less severe injuries or those affecting just one limb for example, and LEHs only accept more minor injuries. However, when a patient is in extremis, these Emergency Departments may still be expected to stabilise a patient before arranging onward transport to the MTC. This provides challenges to staff and resources that are no longer seeing this type of patient on a regular basis and yet are called upon to optimise the condition of the most severely injured patients (Beeharry and Moqeem, 2020).

One of the key levers for the successful implementation of trauma networks was the way in which funding was made available to care for these patients (Copas and Moran, 2014, Kanakaris and Giannoudis, 2011). Trauma networks are financed via additional investment from central government which supports a 'best practice tariff' of payment based on key performance indicators being met (McCullough et al., 2014).

In order to provide high-quality care across a range of specialties, it is necessary for the most severely injured patients to be triaged to an MTC, even when a TU is closer to the scene of an incident. According to guidance from the National Clinical Guideline Centre (NICE, 2016c), the MTC must be accessible within one hour, otherwise the patient should still be transported to a closer Trauma Unit. This process of selecting a specialist unit, which may not be the closest, has become known as 'Trauma Unit Bypass' to indicate that the patient has been identified as requiring assessment and treatment in a Major Trauma Centre.

1.2.1 Trauma Unit Bypass

Trauma Unit Bypass (TUB) describes the practice of identifying appropriate patients at the scene of an incident and transporting them to an MTC, in preference to another Emergency Department which may be closer or reached more quickly

(NICE, 2016c). It brought a significant change in practice for ambulance clinicians and pre-hospital care providers in 2012 when the trauma networks were implemented.

In addition to the increase in patient numbers due to trauma unit bypass, the MTC is still required to take non-major trauma from within its own catchment area, as it did prior to the implementation of the trauma network. This therefore increases demand on resources for MTCs. An evaluation of the major trauma system in England (Moran et al., 2018) showed that in patients with moderate or severe injury, an MTC was the initial hospital destination in 61% of cases just prior to the implementation of trauma networks in 2012, but this increased to 72% in 2016/17. For this reason, it is important that the TUB tool does not 'over-triage' less severely injured patients to the MTC. In other words, patients who do not have severe injuries should not bypass a TU closer to the scene of the incident if they do not require the specialist management available at the MTC. Conversely, 'under-triage' could mean that severely injured patients do not receive the care they require if they are taken to a LEH or TU, which may not have the capability to manage their condition adequately.

Under-triage has been particularly noted in elderly patients, a group that is growing in number and significance (Rehn et al., 2009, Harper and Wilkinson, 2021, Jeon and Yu, 2019, Hendrickson et al., 2015, Faqir, 2018, Jarman et al., 2020).This may be because this population has less resilience to injury than younger patients or because their physiological parameters do not respond in the same way (for example due to the effects of medication), and therefore do not activate the triage tool. Recent data from the UK have shown a marked increase in the median age of major trauma patients from 45 years in 2008/9 to 59 years in 2016/7 (Moran et al., 2018). It is therefore vital that any means of assessment is valid across the age ranges.

Once patients have been under-triaged, they may not always then be transferred to an MTC once the extent of their injuries is ascertained. A national peer-review reported concerns that adult patients with an Injury Severity Score (ISS) greater than 14 were not being transferred out of Trauma Units to the MTC and it recommended further work to analyse these instances (NHS England, 2015). Secondary transfers can be more important in some areas, due to travel times and

rural and remote locations (Wright et al., 2021) and can result in delays to definitive care (Haslam et al., 2020).

An accurate trauma triage tool to predict major trauma whilst avoiding significant over-triage is essential to a successful trauma system. This study was necessary to provide a performance base line for a triage tool, and to offer improvements with the intention of mitigating the effects of under- and over- triage described. The setting for this study (University Hospital Southampton) uses the Wessex Trauma Unit Bypass triage tool, and this is described in more detail in the following section.

1.2.2 Trauma Triage Tools

Prehospital decision support tools can take many forms, from knowledge banks and guidelines to triage systems and protocols (Hagiwara et al., 2011). The appropriate use of clinical decision support tools in prehospital care can contribute to improvements in patient outcomes and optimisation of resources (Bashiri et al., 2019). Field trauma triage, as it is known in the USA, is carried out in EMS systems worldwide (explored in Chapter 2) and has been a formal process since the 1980s (Knopp et al., 1988, Mackersie, 2006) to facilitate transport to the appropriate level of trauma care (American Trauma Society, 2022). Field triage is complex with EMS providers placing significance on speed of decisions, relying on initial impressions over precise measurement of vital signs and consideration of specific triage tool criteria (Jones et al., 2016).

To assist ambulance crews to make complex decisions around transport, a number of triage tools have been developed with the aim of identifying patients who are severely injured, without over-loading the system and inappropriately bypassing other Emergency Departments with patients with lesser injuries (Thompson et al., 2019, SWASFT, 2020a, NICE, 2016c). A commonly used protocol is that published by the American College of Surgeons (ACS, 2014) which has been widely evaluated in the literature (Chapter 2).

In the UK, formalised trauma triage began with the implementation of the London Trauma Networks in 2010 (Beak et al., 2020), followed by the rest of England in 2012 (Moran et al., 2018) and more latterly Northern Ireland (Redmill, 2017), Wales (CTMUHB, 2020) and Scotland (NHS Scotland, 2020). Currently, a number of triage tools are in use throughout England by the various ambulance services (Beak et al., 2020, Freshwater and Crouch, 2015, McQueen et al., 2014, SWASFT,

2020a, Thompson et al., 2019) although large variations exist between them (Holt et al., 2020).

The Trauma Unit Bypass (TUB) Tool (Appendix 1) which has been in use in Wessex since the inception of the Trauma Network, was based on the ACS (2012) guideline, although crucially, the mechanism of injury component was removed. This means that any validation of the ACS tool is not directly applicable to the Wessex tool due to the modifications made. The development of the Wessex tool was via expert opinion and consensus of senior clinicians in the region. The performance of the tool has yet to be fully evaluated for its accuracy in practice. Potter et al. (2013) carried out a small database analysis of 175 patients who presented to their MTC in Plymouth and were found, upon discharge, to have an ISS of greater than 15. The Wessex triage tool was found to have a sensitivity of 53% although they made some assumptions where data was missing which may affect their calculations. The specificity of the tool was not assessed in this paper. However, they did look at various components of the decision-tree and found that it performed poorly in the elderly, where the predominant mechanism of injury was a fall from low height.

The tool is provided to ambulance crews in paper format and as a smartphone application (Freshwater and Crouch, 2015). The Wessex Trauma Unit Bypass (TUB) Tool was initially used by Thames Valley, Severn and Peninsula networks, covering the whole of the South West of England, including the Isle of Wight, but changes have been made to the tool in SWASFT more recently. Although the tool remains similar to the Wessex version, it has for example substituted ‘open pneumothorax or flail chest’ for ‘extensive chest wall injury’ and added ‘bilateral femoral fracture’ to help identify those injuries which may need specialist input (SWASFT, 2020b). The Wessex tool is in use throughout the whole of the South Central Ambulance Service (SCAS) and Isle of Wight Ambulance Service (IOWAS) areas.

Validation of decision support systems should occur not only to evaluate their effectiveness, but also to ensure acceptability by users (Sojda, 2007, Sailors et al., 1996). This may be best achieved by a two-step process, first to test the tool under controlled conditions and then to evaluate the use of the tool in a randomised trial (Lamy et al., 2010). However, there is limited application for a decision support tool

that has high diagnostic quality if it does not result in improvements in clinical management (Ramnarayan et al., 2003).

The use of an unvalidated tool in clinical practice may result in poor compliance with the triage criteria, as there can be temptations by clinicians to alter the tool when they believe that performance may be improved. Porter et al. (2018) report that where paramedics lacked confidence in the performance of a triage tool, they described how they would override it and transport a patient according to their own, independent decision. Compliance with triage by clinicians in the emergency setting can be low (Christensen et al., 2011, Cheney et al., 2008, Bennett and Hardiker, 2017). This has been shown to occur more frequently in specific cases, such as mechanism of injury, or in intoxicated patients and when carried out by non-permanent members of staff (Linder et al., 2019). A study from the Netherlands found that pre-hospital providers were influenced in their choice of hospital by how the patient was received in particular centres and this caused non-compliance with trauma protocols (Galazkowski et al., 2018). This study demonstrated that education of clinicians could improve triage decisions, particularly in identifying older patients who required specialist care.

A systematic review investigating compliance to prehospital trauma triage protocols worldwide found that even when all components of a triage tool (vital signs, injury type and mechanism of injury) were met, 10-15% of patients were not transported to a higher-level trauma centre (van Rein et al., 2018b). In Wessex, cases where patient care or outcome may have been improved are regularly reviewed by the network governance team. Recommendations for improvements are frequently made and shared with others in order that care can be improved. Suggestions have been made that certain wording or physiological parameters are altered, based on one case or adverse incident. Therefore, it can be seen that a robust validation, based on sound methodology, is required to be carried out on the TUB tool and, if necessary, alterations made to improve its performance.

This perception of organisational support for decisions made by UK paramedics in the field has been described in the literature with clinicians describing using the outcome of the decision support tool to back up a decision they had already made (Porter et al., 2018, O'Hara et al., 2015). Compliance with trauma triage protocols has been found to be highest in inexperienced providers and also in those who are supervising paramedics in training (van Rein et al., 2018b). A Swedish study of

prehospital ED bypass for older patients described clinicians using a triage tool to inform treatment destination, for this decision to then be over-ruled by the receiving clinician at the specialist centre. However, it does not comment on whether this affected compliance with the tool or future triage decisions (Vicente et al., 2014).

1.2.3 Trauma Registry

The Trauma Audit and Research Network (TARN) was established in 1988 and has developed into an independent monitor of trauma care in England and Wales (Dixon, 2014). It is the largest trauma registry in Europe (Bouamra et al., 2006) although there have been proposals to combine it with other similar registries to create a continent-wide dataset (Ringdal et al., 2008) this has so far not been realised. Information has been contributed by 175 different hospitals of a range of designations (Beuran et al., 2014). Submission by Major Trauma Centres is mandatory and inclusion of patients is dependent on a number of criteria based on length of stay and pattern of injury (TARN, 2014). However, there are a number of serious conditions not included; burns, asphyxia and drowning (Ringdal et al., 2008). In particular, burns are often managed differently to other trauma (unless they are concomitant with other injuries) with referral to specialist burns units rather than MTCs (Brady et al., 2019). Proximal femur or pubic ramus fractures in patients over 65 years old are also specifically excluded (de Jongh et al., 2010). All cases are assigned an Injury Severity Score (ISS) which measures the overall severity of injuries. Efforts continue to improve the accuracy and completeness of information contained within this database (Jenkins et al., 2020).

1.3 Pre-hospital emergency care in the UK

1.3.1 Ambulance workforce

Paramedics were first registered in 2001 in the UK. In May 2021, there were 31,084 on the paramedic register with the Health and Care Professions Council (HCPC, 2021b). Operational paramedics make up 38% of ambulance staff with ambulance technicians forming 16% (NHS England, 2019). The latter are not registered professionals but still have a degree of autonomy and may be the most senior clinician on an ambulance crew. Finally, other operational staff, namely emergency care assistants or support workers form 19% of ambulance staff and will work alongside paramedics or technicians.

This period of time since the first paramedic registration has seen the increased professionalisation of the paramedic workforce (First et al., 2013, Woollard, 2009, Gallagher et al., 2016) from that of a trade (McCann et al., 2013) to a recognised healthcare provider (McCann and Granter, 2019). This has allowed the paramedic workforce to have more influence over education, training, career development and participation in the wider health economy and to have a greater voice over services which were traditionally managed solely by the medical profession. However, it is interesting to note that, due to current legislation, ambulance trusts are still required to have a senior doctor and nurse or midwife at board level but there is no requirement for an equivalent paramedic post (Monitor, 2013).

In 2021, the educational threshold to register as a paramedic was raised to Bachelor degree with honours from certificate of higher education (HCPC, 2021a). Although this change does not affect existing paramedics, it goes some way to developing the profession and providing a workforce able to deal with contemporary healthcare. It has also contributed to the recognition of paramedics as independent clinicians. This has led to many other roles now being open to paramedics, such as Advanced Clinical Practitioner, in a range of settings including primary and emergency care (College of Paramedics, 2017). Many paramedics now also work in education, leadership and research and so the number of registered paramedics does not reflect the number working directly in delivering pre-hospital emergency care.

Pre-hospital emergency medicine is a sub-specialty area of medical practice with its own curriculum and training programme (IBTPHEM, 2020). Whilst physicians have participated in pre-hospital care for many years, often as volunteers, there is now a formalised route to become qualified to deliver emergency care in this environment for doctors. Many of these doctors work on specialist teams, often alongside critical care paramedics, to deliver enhanced care such as pre-hospital emergency anaesthesia (PHEA).

Therefore, it can be seen that following a 999 call to the scene of an incident, a range of healthcare professionals could attend, from unregistered staff to physician-led teams. Triage to an appropriate receiving hospital will be carried out by all of these clinicians, and so any decision support tools must be accessible and useable to all.

1.3.2 Ambulance services in England

In England, recent figures describe 10 ambulance trusts responding to 10 million 999 calls every year (NHS England, 2019) and media reports show that this number continues to rise as many people use this means to access both urgent and emergency care. Of these calls, a proportion do not receive an ambulance response (hear and treat) and a larger cohort are assessed by ambulance staff and discharged on scene, often with referral to another healthcare provider such as a general practitioner. Only two-thirds of patients are conveyed to hospital (NHS England, 2019).

The performance of ambulance services is measured largely against a set of time-based targets (England, 2022). Calls are categorised, according to likely urgency, and a target response time assigned to each. The intent is that the most serious cases receive a rapid response, but this relies on accurate triage being carried out by a non-clinical operator receiving a telephone call. Computer software utilises algorithms to collect key information and assign a call code with the emphasis being on providing a safe system which can identify patients in cardiac arrest (Turner et al., 2017). Whilst the emphasis is placed on patients who are pulseless and apnoeic, this system may not adequately prioritise patients who have suffered major trauma but are still conscious. For example, external bleeding may be immediately obvious and able to be conveyed to a call-taker, whereas occult bleeding may not.

1.3.3 Paramedic research

Previously, the paramedic role was seen as very practical, rather than academic, and there was little appetite for research in the profession (Wood, 2012). However, more latterly there has been an expectation that paramedics should contribute to the evidence in emergency care (Rosser, 2012). With the professionalisation of the paramedic role (1.3.1) there is a necessity to undertake more responsibility for research (Maguire et al., 2016, Jones and Jones, 2009), particularly around emergency medical services and prehospital care (Pocock et al., 2016). It is now seen as a core component of paramedic practice and the need for specialist research paramedics has been identified and implemented (Coppola, 2018).

The prehospital environment presents challenges for conducting research, however, these are not insurmountable and should not preclude conducting high-

quality studies in this environment (Pocock et al., 2016). Each clinician can have a relatively small number of cases per shift, when compared to those working in static sites, due to the travel time required between patients. This means that fewer interventions may be carried out by a researcher in the field than may be possible by others. The nature of the work is unpredictable. For instance, external researchers may join a paramedic for a short period to observe their practice and have a shift with few incidents, reducing exposure to the working practices of their subject. There are few opportunities to observe in person, not least due to space and safety constraints of working within a vehicle. However, as technology improves, small cameras have been fitted to ambulances and staff, along with recording devices to capture the pre-hospital environment and staff at work (Dewar et al., 2019). There are information governance issues around this type of data capture and it is vital that systems exist to store, distribute and destroy images that may include patients and other staff.

As registered professionals, paramedics have a responsibility to ensure that the rights of their patient are protected whilst participating in research (HCPC, 2018). There are often issues around consent in emergency care, as the patient may not have capacity to understand the implications of participation and the clinician will be expected to act in their best interests (Department of Health, 2005). This may occur for various reasons such as severity of injury, level of consciousness and impairment caused by illness or intoxication. By the very nature of some of the high acuity calls attended by ambulance staff, there will frequently be insufficient time to obtain consent from patients. Therefore, it can be seen that robust procedures and review must be in place to ensure that research in this challenging environment is conducted in an ethical manner (Griffiths, 2012). There is a legal framework which permits researchers to involve adult patients who lack capacity for consent to participation in research (Great Britain, 2019). In conjunction with the Mental Capacity Act (Department of Health, 2005) this provides safeguards for patients in the emergency phase who may lack capacity due to the nature of their injuries (Woods, 2016).

As student paramedics must now all complete an honours degree at undergraduate level, and more go on to undertake Masters and Doctoral level study, the research output from paramedics is set to grow, both in the UK and internationally. Ambulance service staff have been shown to value participation in research (Pocock et al., 2016, Rhys et al., 2018). An increase in scholarly output

around paramedicine has recently been demonstrated (Beovich et al., 2021) but much of this work originates from Australia and the USA and a high proportion is not produced by paramedics themselves. Increasingly, UK ambulance services are engaging in high-quality research and designing systems that streamline systems of research management and governance (McLure et al., 2010). Specific research governance training has been developed for paramedics who will be involved in research studies to avoid the requirement for Good Clinical Practice training and updates for large numbers of staff (Lawrence et al., 2016). Paramedics are one of the 14 professions that form the group of Allied Health Professions (AHPs), with the College of Paramedics (CoP) being a member of the AHP Research Network (AHPRN) (Williams et al., 2014). This allows paramedic researchers to network with colleagues from other professions and to explore grant funding and career development whilst accessing support in planning and implementing research.

There is now a National Ambulance Research Steering Group which represents ambulance research in the UK, having representation from each ambulance service in the country, and provides a repository of research from these organisations (NARSG, 2021). The need for organisation, collaboration, support and implementation of specialist roles for researchers in this field is being increasingly recognised and recommended (Griffiths and Mooney, 2012, Jones and Jones, 2009, Maguire et al., 2016, McClelland, 2013, Burges Watson et al., 2012). Compliance with research protocols can be influenced through an understanding of a variety of human factors, and by demonstrating organisational support and providing education to participants (Pocock et al., 2016). Failure to acknowledge individual paramedic's perspectives around ethical considerations can however jeopardise the success of prehospital trials, and so paramedics should be involved in all stages of trial development (Charlton et al., 2019).

1.3.4 Paramedic clinical decision making

Whilst an in-depth investigation into how paramedics make clinical decisions on scene at an emergency is outside of the scope of this project, it is important to identify some of the challenges that exist. Although tools and guidelines are in common use within all areas of practice, they are used in conjunction with clinical decision-making and the practitioner's own skills, knowledge and experience.

The use of clinical decision making tools can create a cognitive pause and assist the clinician in moving from rapid System 1 to slower, more deliberate, System 2

thinking (Kahneman, 2012). As emergency situations experienced by prehospital providers can emphasise speed, this transition to a more analytical thinking style may need to be deliberately induced by the use of a decision support system (Jones et al., 2016). It has been proposed that decision support tools can improve the clinical assessment of prehospital providers (Hagiwara et al., 2011, Halter et al., 2011). Better understanding of paramedic clinical decision making can improve cognitive performance in the prehospital environment (Perona et al., 2019).

There are many factors that can influence paramedic decision making, acuity of the patient's condition, and the complexity and time-critical nature of interventions which must be provided, can be significant (Jensen et al., 2009). This, combined with inherent biases and fallibility, and the sometimes austere environment experienced by paramedics, can make errors that are difficult to avoid (Collen, 2017). Human factors are increasingly studied in relation to paramedic practice and these theoretical concepts have been applied to modern practice to assist clinicians in recognising challenges and mitigating for them (Rutherford, 2020). The limitations of time, environment and equipment can affect the ability to make critical decisions but performance can be improved through training and the implementation of routine reflective practice (Perona et al., 2019). Uncertainty is common in the prehospital emergency environment and strategies can be employed to mitigate for this, particularly to assist novices in avoiding mistakes (Harenčárová, 2016).

Clinical decision support systems can result in more accurate triage of patients and reduced on-scene time, ultimately improving patient outcomes (Bashiri et al., 2019). Trauma triage is complex and multi-factorial and the usability of triage tools is important in them being adopted and utilised by paramedics in the field (Jones et al., 2016). Technological solutions may be employed (Freshwater and Crouch, 2015, Bennett and Hardiker, 2017) but consideration must be given to any applications which require a stable internet connection or may not be reliable for other reasons in this type of setting.

Experienced paramedics have been found to rely less on decision making tools than their more junior colleagues and to exercise their own judgement more readily (Reay et al., 2018). Cognitive reasoning in trauma triage has been described as more heuristic than algorithmic, driven by clinician judgement rather than specific triage criteria (Newgard et al., 2011a). Paramedics have described how triage tools

can assist the new or inexperienced provider to triage in major incident situations but that those with more experience were less likely to use these tools and relied on ‘gut feeling’ or recognising a patient who ‘looks sick’ (Arbon et al., 2008). This describes the process of pattern recognition (Collen, 2017) or intuitive thinking (Shippey and Rutherford, 2020) in the experienced paramedic. However, both student and experienced paramedics in Canada were shown to prefer and perceive that they have the ability to use rational over experiential thinking (Jensen et al., 2016).

The nursing process does not directly articulate to the complex and often unstructured role of the paramedic (Carter and Thompson, 2015) and additional factors may need to be considered such as available resources and the environment (Reay et al., 2018).Therefore, research into decision making by nurses should not be applied wholesale to paramedic practice. This can be a pitfall when evaluating prehospital studies in this area, as some European EMS systems are staffed by nurses rather than paramedics. More high quality research is required to evaluate the effects of decision support tools on the assessment of patients who are acutely ill or injured and access EMS (Hagiwara et al., 2011).

There are a number of factors to consider when evaluating the use of a pre-hospital decision support tool for use by ambulance clinicians. Whilst the paramedic profession is relatively new compared to others in healthcare, it is rapidly developing with prehospital care becoming increasingly complex. Paramedics are autonomous practitioners at the point of registration, working in an often uncontrolled environment (College of Paramedics, 2021). There are specific challenges in managing high acuity cases, in sometimes austere conditions. Decision support tools, such as a trauma triage tool, can support clinicians in clinical practice, reducing cognitive load and facilitating safe decisions. However, paramedics are also expected to exercise their own clinical judgement, and use evidence-based practice, to make decisions in the best interest of patients (HCPC, 2018).

1.4 Study rationale

The focus of this study was developed in light of my own experience in both the pre-hospital phase of trauma care and the emergency department management of these patients. Following previous research (Freshwater et al., 2014) the variety of

patients transported by helicopter to University Hospital Southampton (UHS) was identified and so an interest in the way in which they were triaged to a large teaching hospital was developed. This work suggested that some patients were being flown to Southampton due to the provision of a suitable helicopter landing site (HLS) rather than clinical need. The consequences of this are many, not least of all that the helipad can only be used by one aircraft at a time and so, if the HLS is occupied inappropriately and another, more seriously injured patient has to be diverted to a secondary landing site, delay in their treatment may occur.

Working in the Emergency Department at UHS means that the impact of over-crowding in the resuscitation room is a real, lived experience. Pressure on staff and resources increases with each high-acuity patient and there are only a limited number of bed spaces in this area. The effect of over-triage is to utilise this space when it may not be required. The effect of over-crowding in Emergency Departments is well documented and poorer outcomes and performance are reported in several papers (Abir et al., 2019, Bernstein et al., 2009, George, 2015, McCarthy, 2011, Morley et al., 2018, Sun et al., 2013, Jones et al., 2022).

There are services only currently available consistently in MTCs, such as dedicated senior trauma team leadership, which are shown to improve outcomes (Davenport et al., 2010, Lecky, 2002). However, it is important that they are available when they are required for the sickest patients and are not inappropriately utilised when a patient could be adequately managed within a Trauma Unit. The process of Trauma Unit Bypass (TUB) (1.2.1) aims to appropriately allocate patients to the resources that meet their care needs for the injuries they have sustained. This process is facilitated by the use of triage tools, of which there are several in use throughout UK trauma networks (1.2.2). Clinical decision making in the prehospital environment can be challenging, and such tools aim to support safe and appropriate triage for a range of clinicians in this field (1.3).

The purpose of this study is to evaluate one of the TUB tools used in an established trauma network in England, and to suggest improvements to enhance its performance in predicting major trauma requiring transport to a specialist MTC.

1.5 Aims and objectives of the study

The objective of this research is to measure the accuracy of the Wessex Trauma Unit Bypass (TUB) tool in predicting a high Injury Severity Score in patients who have been subjected to trauma.

1.5.1 Definitions used to describe cases

Individual cases were assessed against the current Trauma Unit Bypass tool in use by pre-hospital clinicians in this region. Any case that met any of the anatomical or physiological criteria outlined had 'triggered' the TUB tool and was considered 'TUB positive' and all other cases were 'TUB negative' (where none of the criteria were 'triggered'). The ISS for each case was recorded with those scoring greater than 15 being defined as having suffered major trauma (an injury severity score equal to 15 is not possible due to the way the score is calculated). All other cases were designated as not major trauma. Each case is therefore categorised as shown below:

Table 1-1 Case categorisation

Categorisation	Definition	Triage category
True positive	Trauma tool triggered and ISS greater than 15	Correctly triaged
False positive	Trauma tool triggered and ISS less than 15	Over-triaged
True negative	Trauma tool not triggered and ISS less than 15	Correctly triaged
False negative	Trauma tool not triggered and ISS greater than 15	Under-triaged

The 'true' results are those cases for which the TUB accurately identifies the patient as either requiring transport to a Major Trauma Centre or being suitable for assessment and management at a Trauma Unit.

False positive cases are those where the TUB tool predicted major trauma but the ISS was less than 15; these cases are defined as 'over-triaged'. The remaining

group, false negatives, are the most concerning and describe patients where the tool predicted major trauma was absent but the patient was found to have an ISS >15 (under-triaged).

'Over-triage' may be described as the situation where clinicians assess the patient's injuries to be more severe or extensive than they actually are. 'Under-triage' has potentially significantly greater consequences and is the case where injuries are not identified or their severity and impact on physiology is unrecognised. The result may be that a patient is transported to an inappropriate location, potentially resulting in a secondary transfer to the MTC and a delay in definitive treatment.

The aim of this study is to measure the accuracy of the TUB tool and, to propose modifications to improve its performance in identifying patients who have suffered major trauma.

1.5.2 Research questions

What is the accuracy of the Wessex Trauma Unit Bypass Tool in predicting patients with an Injury Severity Score of greater than 15?

Are there modifications that can be made to the WTUB Tool in order to improve its accuracy?

1.5.3 Objectives

The objectives of this study are as follows:

- To assess the accuracy of the Wessex Trauma Network Trauma Unit Bypass Tool in predicting major trauma by calculating its sensitivity and specificity in identifying patients with an Injury Severity Score of greater than 15.
- To analyse characteristics of patients and incidents which have been under and over-triaged to identify patients for whom their injuries are not predicted accurately.
- To suggest modifications to the Trauma Unit Bypass (TUB) tool in order to improve accuracy.

- To test the modified TUB tools in order to assess their sensitivity and specificity against the original data set.

Chapter 2 Review of the literature

2.1 Introduction

In order to inform the development of the research question and study design, it was necessary to obtain and review the literature around this subject and identify other similar studies which may have been carried out. This chapter sets out how papers were identified and analysed and presents key findings from the review. The methodology for the literature review is described, including a description of the search strategy, and a summary of the papers reviewed is provided (Table 2-3). The key findings from this review are presented, focusing on study designs employed, the settings in which they took place, and relevant comments on their population samples. The chapter then goes on to analyse the outcome measures used and the performance of each of the triage tools against these, including rates of under and over-triage. Finally, there is a short narrative of a very recent systematic review which has been published and an ongoing UK project which aims to improve trauma triage in this country.

The purpose of this literature search was to understand how other trauma triage tools had been evaluated, either in clinical practice or against retrospective data. This was necessary to ascertain which study methods and data analysis had been employed in order that they could be considered for use in this project. It was important to focus on similar tools, used by EMS providers, in the prehospital environment for identifying patients who needed to be triaged to trauma care. The literature review was also required to understand what was already known about this topic, and where the gaps in the evidence were.

2.2 Methodology

2.2.1 Search strategy

In order to address the points above, the research questions for the literature review were:

> *How are trauma triage guidelines evaluated for use in the prehospital environment?*

and:

How do trauma triage tools perform in identifying major trauma?

The literature search included various terms and their synonyms used to capture the assessment of such field trauma triage tools. Truncations and wildcards were used to ensure that all possible permutations were included. Boolean operators were employed to combine search terms (Table 2-1). The databases MEDLINE, CINAHL and EMBASE were utilised with the following search terms used.

Table 2-1. Search terms

Terms	Field
Trauma OR injury	[Title]
AND	
Prehospital OR pre-hospital OR EMS OR emergency medical service* OR ambulance OR paramedic*	[Abstract]
AND	
Guideline OR protocol OR algorithm OR criteria OR tool	[Abstract]
AND	
Evaluat* OR precision OR accura* OR predict*	[Abstract]
AND	
Triage OR priorit* OR select*	[Abstract]

The initial review of the literature was carried out in August 2018, it was then repeated in October 2021 to ensure additional, newer materials were identified for inclusion in the final thesis. These more recent works were evaluated and incorporated into the literature review as described in this chapter. During writing up of the thesis, an additional systematic review was identified. This review makes an important addition to the literature and is described separately in 2.9.1.

2.2.2 Inclusion and exclusion criteria

The following table outlines the inclusion and exclusion criteria for the literature review. A pragmatic approach was taken to utilising English language papers only

as there was no facility for translation of papers. This appears to be appropriate as many papers from non-English speaking countries were included as they have been published in English.

A time limit of 20 years was selected as the management of major trauma has and continues to change over time. This time period allows for a range of relevant papers to be included but excludes those which are now out-of-date in terms of clinical practice.

Table 2-2 outlines the inclusion and exclusion criteria employed in this literature search. In order to evaluate robust, scientific work, only published and peer-reviewed papers containing empirical findings were included. Had there been a paucity of available material, it may have been considered appropriate to widen the search by considering other work such as theses and conference material, but the search yielded a substantial amount of high quality, published, peer reviewed research and so this was not required. Study protocols were not included as they had not produced results at that stage and so it would not be possible to evaluate their effectiveness.

The population included was selected to be comparable with the use of the Wessex TUB tool. Although there were many papers excluded from review at this stage, some of them are considered elsewhere in the thesis, in particular when discussing specific age populations, co-morbidity and the inclusion of mechanism of injury (Chapter 6). For example, Brown et al. (2011) provide useful insight into how the way in which a patient was injured can influence the severity of their injuries, but the paper was not primarily focused on evaluating an existing decision support tool in clinical practice. The effect of age in the major trauma population is discussed elsewhere in this thesis (5.1.3 and 6.3.1) but was not immediately applicable to the research questions employed in the review of the literature (2.2.1).

As noted above, papers were only included where the intervention was related to pre-hospital trauma triage for standard EMS services and so the exclusion criteria were used to narrow this down to allow comparison. For example, papers which were only concerned with triage to aid dispatch of helicopters to the scene of an incident were excluded. Similarly, outcome measures were related to identification of major trauma for triage purposes rather than to clinician performance or patient outcome following treatment.

Table 2-2. Literature review inclusion and exclusion criteria

Facet	Inclusion	Exclusion
Type of study	• Published and peer reviewed	• Theses, conference proceedings and posters, reports, commentary, letters, guidelines, book chapters and study protocols
Population	• Patients of all ages • Patients involved in all types of trauma	• Specific ages populations • Specific co-morbid states • Specific mechanism of injury
Intervention	• Triage of patients in the pre-hospital environment • Triage carried out by pre-hospital providers • Triage based on hospital specialty (i.e. major trauma centre) • Triage to hospital • Guidelines on triage • Overall triage tool performance	• Triage or streaming of patients in the Emergency Department • Triage by call-centre staff • Triage based on transport modality (e.g. helicopter) • Triage to determine dispatch of resources • Treatment guidelines • Effect of specific physiological or anatomical parameters in triage tool performance
Outcomes	• Performance of triage tool • Ability to accurately identify seriously injured	• Clinician performance or concordance with tool • Patient outcomes following in-hospital treatment
Other	• English language • Published within the previous 20 years	• Not translated to English • Older than 20 years

2.2.3 Title and abstract review

Figure 2-1 demonstrates how papers were excluded from the review. Following the removal of duplicates, a further 248 papers were removed following title review as they did not address the assessment of a tool in pre-hospital practice (using the criteria in

Table 2-2).

Papers were removed on title review for the following reasons:

- Not measuring comparable outcome. For example, outcome was predicting admission or need for secondary transfer.
- Specific population, e.g. paediatrics only.
- Specific population with specific injury, e.g. traumatic brain injury in children.
- Isolated mechanism of injury, e.g. falls or agricultural injury.
- Related to in-hospital triage.
- Investigating experience of using a triage tool or compliance with triage criteria.
- Evaluating criteria for dispatch of EMS resources.
- Related to treatment options for major trauma, for example provision of analgesia.
- Triage was specifically in major incident scenarios rather than standard civilian major trauma incidents and so not comparable as triage threshold can change in mass casualty events to do ‘the best for the most’.
- Only evaluated one clinical variable, for example respiratory rate or end-tidal carbon dioxide measurement.
- Evaluated clinician performance in identifying major trauma rather than the use of a decision support tool.

The abstracts for all remaining papers were then reviewed with 21 being removed at this stage. In addition to the reasons above, papers were excluded at this stage for the following reasons:

- Evaluated trauma triage solely against mortality rather than a measure for major trauma or an indicator for needing specialist intervention
- Related only to utilisation of air assets in major trauma
- Study protocol for further work

- Full paper not available in English (only abstract) and so could not be adequately evaluated within the scope of this study

There were no papers in the literature search from the UK. However, Potter *et al.* (2013) evaluated the sensitivity of the Wessex Trauma Unit Bypass tool in their centre in Plymouth, England. This paper did not appear in the database literature search as it was published in the journal of the Royal Naval Medical Service (JRNMS) which does not appear in the common databases and is not readily accessible. However, it was identified when it appeared in 'suggested research based on your interests' on researchgate.net. This paper was deemed to be extremely valuable to the study as it evaluated the same TUB tool and was the only paper from a UK setting. Therefore, it was included, despite not appearing in the initial search. Full-text of this article was requested via ReasearchGate and kindly provided by the first author. This demonstrates the advantages of networking online with other researchers and sharing work in this manner. Therefore, there were a total of 22 papers for inclusion in the literature review as detailed in Figure 2-1 and presented in Table 2-3.

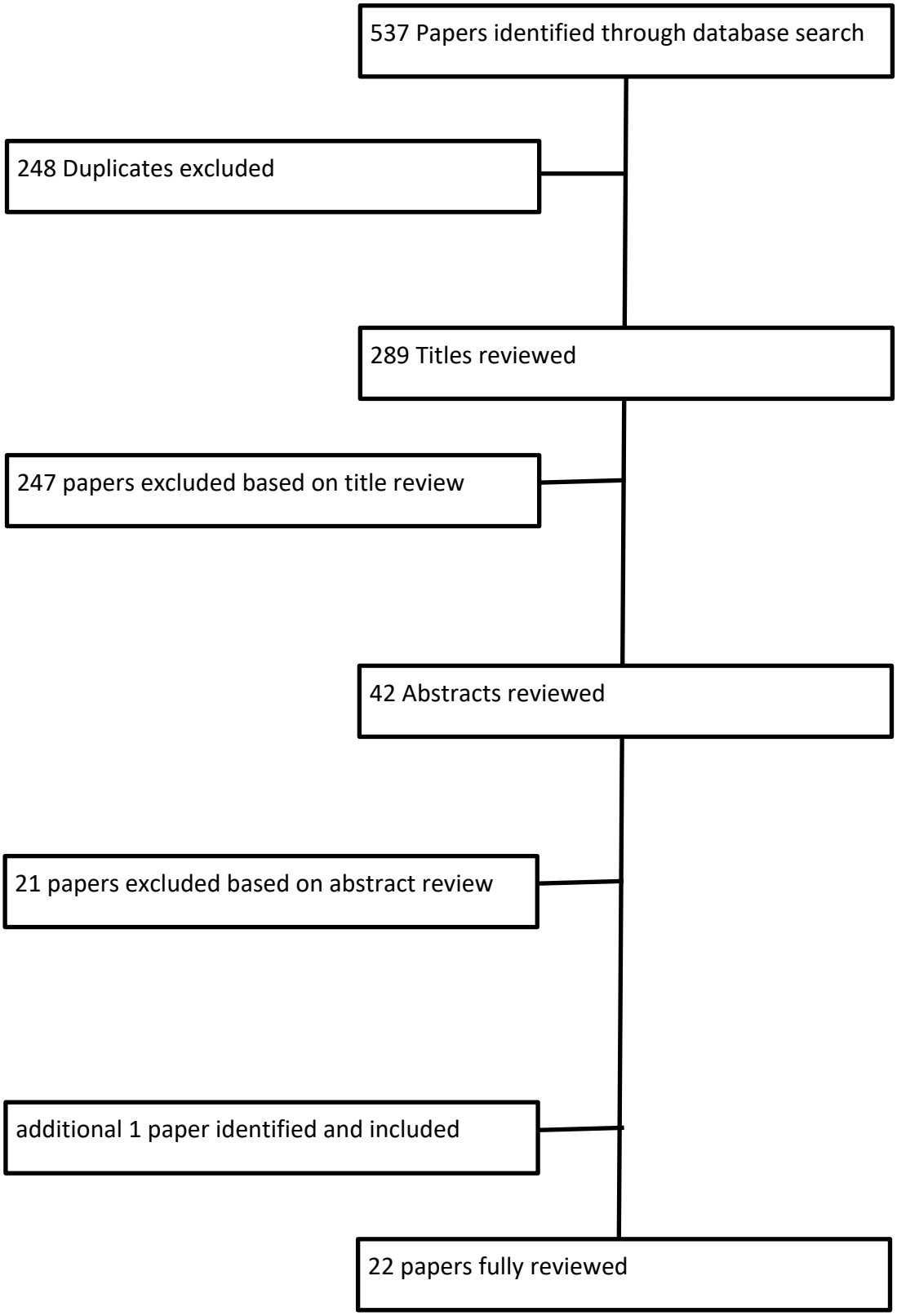


Figure 2-1 consort diagram illustrating review of literature with inclusions and exclusions

Table 2-3 Summary of papers included in the literature review

Authors	Year	Title	Objective	Study type	Strengths (S) and Limitations (L)	Definition of major trauma	Setting	Sample size	Findings
Bouzat, Ageron, Brun, Levrat, Berthet, Rancurel, Thouret, Thony, Arvieux and Payen	2015	A regional trauma system to optimize the pre-hospital triage of trauma patients	To evaluate 1) the quality of the pre-hospital grading protocol to detect the most severe trauma patients and 2) the accuracy of the trauma system procedure to perform an adequate triage	Retrospective study of trauma registry data	S – all levels of TC. Data entered by physicians onto trauma registry. Monitored for completeness and correctness L - only included those who met trauma criteria. Poor compliance with pre-hospital assessment. 100 pts lost due to missing data. 25% had missing triage criteria and this group had higher ISS. Issue around definition of undertriage. Allowed treatment first at lower centre. May make results appear more favourable. Tool evaluated by those who developed it – may introduce bias. Sn&Sp only calculated in group assessed by physicians, not applied to all pts. Discussion that management in physician and paramedic groups the same but this cannot be inferred	ISS >15	France	2572	Sensitivity 92%, Specificity 41%
Brown, Stassen, Bankey, Sangosanya, Cheng and Gestring	2011	Mechanism of injury and special consideration criteria still matter: an evaluation of the National Trauma Triage Protocol	To analyse whether trauma centre need was identified by physiologic and anatomic criteria only	Retrospective study of trauma registry data	S – categorised by presence of TT criteria and TCN. Investigated triage by tool and actual triage by transport. Very large sample size. L – Selection bias may be present as only pts on trauma database. Vital signs from ED, not scene. 26.5% of cases lost due to missing data. Did not compare excluded group to remaining sample. Presence of anatomical criteria from ICD codes rather than EMS notes. Presented discussion that MOIS and SC are more accurate than anatomy and physiology but this is not demonstrated by results. P value for triage criteria <0.01 – not explained. Some confidence intervals for TCN wide. Did not comment on over-triage rate although it appears high.	ISS >15, ICU admission or need for urgent surgery	USA	1,086,764	Sensitivity 49%, specificity 78%

Authors	Year	Title	Objective	Study type	Strengths (S) and Limitations (L)	Definition of major trauma	Setting	Sample size	Findings
Cox, Smith, Currell, Harriss, Barger and Cameron	2011	Differentiation of confirmed major trauma patients and potential major trauma patients using pre-hospital trauma triage criteria	To determine if the trauma triage criteria resulted in under-over-triage and whether the triage criteria were being adhered to	Retrospective study of trauma registry data	Same study sample as Cox et al (2011) L – although sample size is large, 1166 confirmed MT, others minor. Excluded all pts not TT positive or MT present. Therefore no TNs so can't calculate Sp. Large amount of missing data, especially oxygen sats.	Death, ISS >15, ICU ventilation or urgent surgery	Australia	45,332	Sensitivity 91.2%
Cox, Currell, Harriss, Barger, Cameron and Smith	2012	Evaluation of the Victorian state adult pre-hospital trauma triage criteria	To evaluate the performance of their triage criteria and, if necessary, propose refined criteria to improve the under and over-triage rates.	Retrospective study of trauma registry data	S – linked pre-hospital and in hospital data. Included all trauma pts taken to hospital. Undertook modelling of variables using CART. 16 new tools tested. L – presence of higher level paramedic in more seriously injured cases could influence results. 4.2% of MT patients had missing data and were excluded. Characteristics of under-triaged pts not discussed. Doesn't describe how anatomic data collected. Wide confidence intervals for prediction criteria. Insufficient statistical power anatomic and MOI criteria due to infrequency. Does not show how Sn calculated (91.2% in paper below)	Death, ISS >15, ICU ventilation or urgent surgery	Australia	45,332	Sensitivity 95.3%, specificity 62.7%
Dehli, Monsen, Fredriksen and Bartnes	2016	Evaluation of a trauma team activation protocol revision: a prospective cohort study	To evalauate a revision to their prehospital triage protocol	Prospective cohort study	S – combined data sources (including radio reports) to ensure those who did not have TTA included. Prospective study design. L – small sample. Percentages may not be useful e.g. only 37 pts undertriaged. Cannot evaluate individual criteria as eg only 9 pts with low BP. Data to calculate Sn and Sp in paper but not reported. Only basic statistical analysis. Some discussion on under-triage reference anecdote rather than data. Provides evaluation of this service but not readily transferable to other situations.	ISS >15	Norway	324	Over triage 74%, under-triage 15%

Authors	Year	Title	Objective	Study type	Strengths (S) and Limitations (L)	Definition of major trauma	Setting	Sample size	Findings
Dinh, Oliver, Bein, Roncal and Byrne	2012	Performance of the New South Wales Ambulance Service major trauma transport protocol (T1) at an inner city trauma centre	To evalute the performance of a newly implemented prehospital trauma triage protocol in NSW for patients trnsported to an inner city major trauma centre	Observational study	L – local service evaluation. TT protocols not provided so cannot be used elsewhere. Inner city setting so may not reflect rest of state. Inclusion criteria not clear – may have missed some minor injury pts so Sp may be inaccurate. Did not include those transported to lower level centres with ISS>15. Assumes that cases with missing data are TT positive. May over-estimate tool performance. This accounted for 232 added to the 767 in the +ve group.	ISS >15, in-hospital death and/or transferred from ED to operating theatre or ICU	Australia	2664	Sensitivity 63%, Specificity 75%
Dinh, Bein, Oliver, Veillard and Ivers	2014	Refining the trauma triage algorithm at an Austrlian major trauma centre: derivation and internal validation of a triage risk score	To derive and internally validate a clinical prediction rule for trauma triage	Retrospective study of trauma registry data	S – larger sample size than previous Dinh et al (2012) as longer time period. Only small number of cases (15) with missing data. Used derivation and validation data sets to model. Produced a risk score which can be calibrated to meet system requirements. L – vital signs from ED, not prehospital. Only included those with TTA so unclear how under triaged identified. MVC associated with reduced odds of MT. Not clear if all motor vehicles. May be due to inner city location and reduced vehicle speed so may not be transferable.	ISS >15, ICU admission or in-hospital death	Australia	3027	Sensitivity 90%
Henry	2006	Trauma triage: New York experience	To evaluate whether standardised triage criteria, in combination with EMS discretion, would accurately identify	Retrospective study of trauma registry data	S – recommends use of specifically designed EMS report forms to more accurately collect data for TT analysis L – single author paper which describes studies from other papers but with little critique. Uses data from 1994 so may be out of date. Unable to access 1996 data used as only available from US govt. agency.	Major non-orthopaedic surgery, death, ISS>15	USA	29,248	Varied for each measure

Authors	Year	Title	Objective	Study type	Strengths (S) and Limitations (L)	Definition of major trauma	Setting	Sample size	Findings
Lavoie, Emond, Moory, Camden and Liberman	2010	Evaluation of the Prehospital Index, presence of high-velocity impact and judgment of emergency medical technicians as criteria for trauma triage	To evaluate the performance of the PHI, the HVI criterion and EMT judgment for the prehospital triage of injured patients	Retrospective study of trauma registry data	S – combined prehospital and trauma registry data. Prospective data collection. Combines existing triage scores and EMS provider judgement. Statistical analysis appears appropriate. L – Large sample size but only 1113 had MT. if health insurance number missing, case excluded. May have introduced bias (affected 3% cases). EMS provider judgement not adequately described. Used where other criteria not met so may have introduced bias. Not able to understand data quality. Where data missing, assumed to be normal values.	Death within 72hrs, ICU admission within 24hrs or ISS >15	Canada	16,805	Sensitivity 74.2%, specificity 70.0%
Lin, Becker and Lynn	2012	Do pre-hospital trauma alert criteria predict the severity of injury and a need for an emergent surgical intervention?	To evaluate which pre-hospital parameters identify major trauma victims with an emphasis on a need for emergent surgical procedures.	Prospective cohort study	S – Prospective study. L –Small sample. Lack of power for infrequent occurrences of injury. Only includes TT positive so unclear how under-triaged are identified. Makes some assumptions (e.g. pts lying by road assumed to be ejected) but this is not backed up in the data.	ISS >15, require urgent intervention or ICU care	USA	601	Varied for each measure
Macken and Manovel	2005	Trauma bypass in south-eastern Sydney: an 8-year review	Review the outcomes of trauma bypass patients and assess the performance of the current prehospital trauma triage protocol	Retrospective analysis of prospectively collected data	S – data from 8-year period. Prospective. Very thorough approach to data collection and completeness. 200 fields of data per case. Case reports reviewed by nurses and missing data followed up and collected. Included all trauma bypass pts. Included paediatric pts. L – Local service evaluation with limited transferability. Sn could not be calculated as only trauma bypassed pts. Does not define TT criteria used. Does not describe how/if paeds altered	ISS >15	Australia	1990	PPV 18.6%

Authors	Year	Title	Objective	Study type	Strengths (S) and Limitations (L)	Definition of major trauma	Setting	Sample size	Findings
					physiological findings due to differing normal values. Results section is descriptive. Limited data analysis.				
Newgard, Zive, Holmes, Bulger, Staudenmayer, Liao, Rea, Hsia, Wang, Fleischman, Jui, Mann, Haukoos, Sporer, Gubler and Hedges	2011	A multisite assessment of the American College of Surgeons committee on trauma field triage decision scheme for identifying seriously injured children and adults	To estimate the diagnostic value of the Field Triage Decision Scheme for identifying major trauma patients in a large and diverse multisite cohort.	Retrospective cohort study	S – review of the ACS tool published in ACS journal. Cited by 38 other studies. Large sample size (122 hospitals, 94 EMS agencies) L – used software for imputation of missing values. May have introduced some bias.	ISS >15	USA	122,345	Sensitivity 85.8%, specificity 68.7%
Newgard, Hsia, Mann, Schmidt, Sahni, Bulger, Wang, Holmes, Fleischman, Zive, Staudenmayer, Haukoos and Kuppermann	2013	The trade-offs in field trauma triage: A multiregion assessment of accuracy metrics and volume shifts associated with different triage strategies	To evaluate the impact of different field triage schemes for identifying seriously injured patients across a range of sensitivity values	Retrospective cohort study	S – multi-region, multisite study. Adults and children transport by 48 EMS systems to 105 hospitals. Used multiple inclusion criteria to capture all relevant cases. Used classification and regression tree analysis for modelling. L - same study period as Newgard et al (2011) but fewer hospitals – unclear why. Some pts excluded (e.g. discharged from ED) which may introduce bias. Overtriage may be greater than reported. ISS calculated with ICD-9 codes rather than case report abstraction (as done by TARN) and so ISS may be underestimated.	ISS >15	USA	89,261	Sensitivity 87.5%, specificity 62.8%

Authors	Year	Title	Objective	Study type	Strengths (S) and Limitations (L)	Definition of major trauma	Setting	Sample size	Findings
Nowakowski, Nowakowski, Bilinski, Nowak, Wojciechowski, Dworzynski, Golis-Gicwa, Timler, Timler & Timler	2019	Comparison of American guidelines for field triage and Polish criteria as qualification to a trauma center	To compare the Polish model for qualification to a trauma centre and American Guidelines for Field Triage	Retrospective analysis of medical documentation	S – first evaluation of Polish criteria L – Small study. 159 pts with multiple organ injury. Excluded isolated injury (minor cases). No discussion of handling of missing or incomplete data. Descriptive results with limited data analysis. Limitations of study not discussed.	ISS >15	Poland	3173	Sensitivity Polish tool 18%, American tool 91.5%
Ocak, Sturms, Hoogeveen, Cessie and Jukema	2009	Prehospital identification of major trauma patients	Examine the ability of the ACSCOT triage guidelines to identify major trauma patients and evaluate a modified tool	Retrospective study of trauma registry data	S – first evaluation of ACS tool in European setting. Evaluated outcomes of pts excluded due to missing data to avoid bias. Created a new tool to improve performance. L – small sample size. 151 pts in study then matched with randomly selected sample of same size for comparison. EMS reports did not contain all required MOI data and so evaluation of ACS tool may be inaccurate. Numbers too small in anatomic component (e.g. no skull fractures)	ISS >15	Netherlands	302	ACSCOT - Sensitivity 84.1%, specificity 77.5%. New tool sensitivity 92.1%, specificity 79.5%
Potter, Kehoe &Smith	2013	The sensitivity of pre-hospital and in-hospital tools for the identification of major trauma patients presenting to a major trauma centre	Evaluate the sensitivity of the Wessex triage tools	Retrospective database review	L – where data missing, made assumption TUB tool would have identified. May have over estimated TUB performance. Unable to calculate Sp as no pts ISS<15. Small sample size with 10 cases lost to analysis as TTA not recorded. Limited discussion – limitations of study not addressed.	ISS >15	England	171	Sensitivity 53%

Authors	Year	Title	Objective	Study type	Strengths (S) and Limitations (L)	Definition of major trauma	Setting	Sample size	Findings
Rehn, Eken, Kruger, Steen, Skaga and Lossius	2009	Precision of field triage in patients brought to a trauma centre after introducing trauma team activation guidelines	Analyse the precision of guidelines for trauma team activation	Retrospective analysis of prospectively collected data	S – 6 years of data. Thorough description of data analysis in Methods section. L – only included if TTA, AIS code or severely injured so over-triaged not included. Used (1-PPV) to describe over-triage. Made assumptions around physician vs paramedic performance although case mix not comparable. TTA done by ED nurse who may have responded differently to EMS personnel but not explored.	ISS >15, proximal penetrating injury, admitted to ICU for > 2 days, transferred intubated to another hospital within 2 days, dead from trauma within 30 days	Norway	4659	Over triage 74%, under-triage 10%
Tamim, Joseph, Mulder, Battista, Lavoie and Sampalis	2002	Field triage of trauma patients: improving on the prehospital index	To evaluate the predictive ability of the PHI in identifying injury severity and to develop a trauma triage scale that incorporates PHI and other variables to improve the performace of the triage tool.	Retrospective analysis of prospectively collected data. Multi-centre.	S - prospective identification of cases, followed up until death or discharge. Tested existing and new tool. L - data from early 1990s. Lost 55% of cases due to missing data.	Death within 7 days, non-orthopaedic surgical intervention within 4 days, ICU admission within 7 days	Canada	1291	Varied depending on variables
van Laarhoven, Lansink, van Heijl, Lichtveld and Leenen	2014	Accuracy of the field traige protocol in selecting severly injured patients after high energy trauma	To determine diagnostic accuracy and compliance of the field triage protocol	Retrospective analysis of prospectively collected data	S – prospectively collected data. Multisite. Under and over-triage calculated based on actual transport destination. L – included pts with High Energy Trauma but this is not defined in the paper. 105 pts lost to missing data.	ISS >15	Netherlands	1607	Sensitivity 89.1%, specificity 60.5%

Authors	Year	Title	Objective	Study type	Strengths (S) and Limitations (L)	Definition of major trauma	Setting	Sample size	Findings
van Rein, van der Sluijs, Houwert, Gunning, Lichtveld, Leenen and van Heijl	2018	Effectiveness of prehospital triage systems in selecting severely injured patients: Is comparative analysis possible?	Evaluate and compare prehospital trauma triage system quality worldwide and determine effectiveness in terms of under-triage and over-triage for trauma patients	Systematic review	S – used scoring system to critique all papers L – limited search criteria may have reduced number of papers for review.	n/a	n/a	n/a	n/a
van Rein, van der Sluijs, Voskens, Lansink, Houwert, Lichtveld, de Jongh, Dijkgraaf, Champion, Beeres, Leenen & Heijl	2019	Development and validation of a prediction model for prehospital triage of trauma patients	To develop and validate a new prehospital trauma triage protocol to improve current triage rates	Prospective, multicentre cohort study	S – prospective, multicentre study. Two data sets, one for design of tool and one for validation. Thorough description of data handling and analysis provided. L – missing data addressed with imputation. Validation data set had higher rates of missing values which may have introduced bias. New tool requires computation and so only available in app form, not described in the paper so cannot be replicated by other systems.	ISS >15	Netherlands	4950	Sensitivity 88.8%, Specificity 50%
Voskens, van Rein, van der Sluijs, Houwert, Lichtveld, Verleisdonk, Segers, van Olden, Dijkgraaf, Leenen and van Heijl	2018	Accuracy of prehospital triage in selecting severly injured trauma patients	To prospectively evaluate the quality of the field triage system to identify severly injured adult trauma patients	Retrospective analysis of prospectively collected data	Use same data set as van Rein et al (2019) S – study conducted in same region as van Laarhoven et al (2014) and so comparisons can be made. ACS tool evaluated so may be transferable to other settings. Included all pts transported with high priority so includes over-triage. L – excluded pts if unable to calculate ISS	ISS >15	Netherlands	4950	Under-triage 63.8%, over-triage 7.4%

2.2.4 Study designs used by existing research

One of the studies by van Rein et al. (2018a) is a systematic review of the literature. The remaining studies are concerned with evaluating the performance of trauma triage tools in a particular system or country. Most papers utilised trauma databases containing routinely collected data with the addition of records from hospital and/or EMS systems (Table 2-3) although no such data source was available for the Polish paper (Nowakowski et al., 2019) and so they had to create a new data set from a review of clinical notes (although the sample size was only 159 patients).

Macken and Manovel (2005) employed experienced trauma nurses to review ambulance case sheets. This has the benefit over non-clinical staff of potentially identifying more nuanced information which may not be immediately apparent to researchers who may not understand the nature of the data they are interrogating. In addition, this study ensured data completeness by contacting ambulance stations to follow-up any cases where records were incomplete. Whilst this is good practice, it is likely to have been time and resource intensive. This is in contrast to Tamim et al. (2002) who removed 55% of their records from the data set which was analysed due to incompleteness. Whilst they did verify there were no substantive discrepancies in demographics between those records removed and those retained, it may have introduced bias. For example, the most severely injured cases can be the most challenging to manage on scene and en route to hospital and so it may be that record keeping is neglected in order to focus on care of the patient. This may have introduced bias by removing some of the most severely injured or critically ill patients. The completion of records can be incentivised, for example in the UK where the payment for results system rewards MTCs for data completeness within TARN.

Due to the large number of patients in their study population, Cox et al. (2011) utilised a software solution to link data between hospital records and the trauma registry data. This provided 93% accuracy with the remaining cases being manually reviewed.

A prospective means of data collection was utilised by Bouzat et al. (2015) with the on-scene physicians not only completing data collection forms contemporaneously but also entering the data into an electronic database. The opportunity for introducing bias is high here as the clinicians are aware that their performance in

assessing patients is being evaluated. They may also have been more fastidious in ensuring all data were recorded at scene (for example physiological values) as they were part of a trial. Other studies have employed a retrospective review of routinely collected data which is more likely to represent the everyday work of ambulance crews. Voskens et al. (2018) also employed a prospective data collection method which allowed them to collect specific information not routinely recorded such as Revised Trauma Score. They then retrospectively applied the field triage criteria to the data rather than asking clinicians on scene to record their transport decision contemporaneously. A Dutch study by van Rein et al. (2019) also prospectively collected data but subsequently utlilised trained coders to apply the Abbreviated Injury Score (AIS) to each case. These approaches are more likely to replicate standard practice in the field and therefore reduce bias.

An alternative approach to missing data was utilised by Rehn et al. (2009) in that where data were missing, they were substituted with normal values. This may have some value to it as physiological findings are more often than not in normal range but an alternative may have been to look at other values and adjust accordingly (for example, if blood pressure was low then it is likely that heart rate would be high). In one of the Canadian studies (Lavoie et al., 2010) the researchers were aware of a convention by EMS providers to leave blank fields which were considered to represent ‘normal’ status and so they had a valid reason for adopting an approach of substituting missing data with values representing stable physiology.

2.3 Study settings

Despite the significant increase in published papers relating to field triage (Sasser et al., 2012) there still has not been a complete evaluation of a UK tool in the literature. Most of the papers are from the USA (n=5) and Australia (n=5) with the remainder from the Netherlands (n=4), Canada (n=2), Norway (n=2) and single papers from France, Poland and the UK plus a review of international literature.

The important point to note in the international nature of the papers is that many countries have EMS systems which differ from the ambulance service provision in the UK. For example, in the US, government provided services are generally within the fire department but there are many hospital-based and other private organisations providing pre-hospital transport and care, alongside voluntary services, particularly in rural and remote communities. In Canada, there is great

regional variability in the level of care provided by pre-hospital clinicians and also in the funding models with subscription-based services being common (Kuimi et al., 2015). The French system has a great deal of physician delivered pre-hospital care (Bouzat et al., 2015) whilst in the Netherlands it is largely provided by specially trained nurses (van Laarhoven et al., 2014). This differs from the UK where the NHS provides ambulance care, delivered by paramedics who are registered with the Health and Care Professions Council, and supporting staff. There is now widespread critical and advanced care provided by physician-paramedic teams, usually within air ambulance services which are charity funded in England (1.3).

Papers from various countries may have differences in the type of patients they see, for example studies from the United States tend to have a higher level of penetrating injury (predominantly gunshot wounds) and the French study (Bouzat et al., 2015) was from a mountainous area with a large number of skiing and mountain sports injuries reported.

Voskens et al. (2018) note that all patients within their area of study could access a Level I trauma centre within 15 minutes whereas this can be much higher in some areas, with the Wessex TUB tool allowing transport up to 60 minutes to reach a specialist centre. In Norway, population is much more sparse with significant distances (up to 250km) between hospitals (Dehli et al., 2016).

The variation in patient severity mix and the organisation of local trauma systems is cited by Rehn et al. (2009) as to one of the reasons international consensus around field triage has not been reached.

2.4 Study samples

The composition of the study sample varied greatly from a huge trauma registry study by Brown et al. (2011) from the USA which included 1,086,764 records to a small Dutch study which included 151 major trauma patients with a control group of the same size with minor injuries (Ocak et al., 2009). Obviously, smaller studies such as that by Dehli et al. (2016) and Nowakowski et al. (2019) will have difficulties achieving statistical significance. For example, in the former study only a total of 92 patients received an emergency procedure in the hospital and in the latter only 21 patients fulfilled the local trauma triage criteria. Consequently, the Polish paper is very descriptive with limited analysis of the data although the authors did recognise these limitations.

The study by Tamim et al. (2002) included trauma patients aged 15 years or over. It is not clear if this is because their facilities do not accept paediatric patients, whether it was related to the database inclusion or if there was another reason such as ethical approval. This study identified patients at the time of the call to EMS and followed them up until death or discharge. Despite this approach, they still had a large loss of data due to incomplete records. Voskens et al. (2018) removed patients under 16 from their study population but did not indicate the rationale for this and the same team applied these criteria to their later paper (van Rein et al., 2019). The remaining studies included patients of all ages.

2.5 Definition of Major Trauma

The majority of papers reviewed here use a definition for major trauma which includes an Injury Severity Score (ISS) of greater than 15. The ISS is an anatomical scoring system, developed in the 1970s (Baker et al., 1974) that provides an overall score for patients with multiple injuries. The ISS can only be calculated once imaging and investigations have been carried out and therefore it is not of use as a triage tool. A study conducted by Rowell et al. (2011) found that the accuracy of ISS in predicting mortality was vastly different between penetrating injuries, for example gunshot and stab wounds, and blunt trauma such as that usually sustained in road accidents. This mortality difference was particularly noted in those that had suffered a head injury. Some variances in calculating ISS by various healthcare providers and non-clinicians were found by MacKenzie et al. (1985) although reliability was improved when medical notes were comprehensively completed and coding staff were well trained. The main limitations of this scoring system is that it relies on another calculation (Abbreviated Injury Scale) and so if this is incorrectly calculated, the ISS will be inaccurate. Also, there is no weighting for various body parts involved and various combinations of injuries can result in the same score. In fact, it decreases its ability to assess injury severity in patients with multiple injuries in the same anatomic area by taking only one highest AIS score from any single anatomic area (Champion et al., 1989). However, it does provide a globally recognised means of calculating the severity of trauma and this has the benefit of allowing comparison of different triage tools.

A study by Schroter et al. (2019) demonstrated that, even using a printed score sheet, pre-hospital physicians found it difficult to predict the ISS whilst in the field. Several of the papers (Brown et al., 2011, Cox et al., 2012, Cox et al., 2011, Dinh et

al., 2012, Henry, 2006, Lavoie et al., 2010, Lin et al., 2012, Rehn et al., 2009, Tamim et al., 2002) also use ISS but in combination with other parameters, including the requirement for emergency surgery, as an additional measure to ascertain if a patient had suffered major trauma. This was deemed to be immediate life-saving procedures rather than other, mainly orthopaedic operations. Intensive Care Unit (ICU) admission and mechanical ventilation whilst in ICU were also used as measures of major trauma by these papers. Cox et al. (2011, 2012), Dinh et al. (2012), and Lavoie et al. (2010) also used death of the patient to define major trauma. Whilst this certainly signifies severe injury, it is not possible to know if these patients were so badly injured that they were likely to die regardless of interventions carried out and so their destination was less relevant. It could be argued that for them to have any chance of survival, they should be transported to an MTC although there is an argument for treatment as close to home as possible in order that families can readily be with the deceased. These studies, with the exception of Dinh et al. (2012) all linked pre-hospital and in-hospital records and contained sizeable samples sizes.

Patients with major injuries who required treatment at a trauma centre were defined by Tamim et al. (2002) as one or more of the following criteria; death in ED or within 7 days, surgical intervention within 4 days (non-orthopaedic or non-plastic) or ITU admission within 7 days. This is an interesting and pragmatic approach to the definition as it looks specifically at whether the patient required the intervention of specialist teams within a trauma centre, rather than a scoring system. This, it could be argued, more accurately measures trauma centre need and the impact on a system than purely a numerical score. However, it is not graded in any way which indicates severity of injury and there is no difference in for example a 1 day ITU stay or a prolonged period of intensive care. This paper contains 3-years of data, although it is from the early 1990s. This means the data and findings may not be representative of or transferable to modern trauma care.

In the limitations section of their paper, Lavoie et al. (2010) discuss at length the controversy around which patients actually benefit from being transported to a higher level trauma centre. In particular, they note this in relation to patients who are solely defined as suffering from ‘major trauma’ by having an ISS of greater than 15. This is acknowledged to be an arbitrary benchmark of severe injury by Dinh et al. (2012).

2.6 Protocol compliance and clinician performance

Macken and Moanovel (2005) noted over an 8-year period that the performance of the triage tool diminished with the positive predictive value declining over time. However, they were unable to identify the reasons for this with one suggestion being that it was due to variable application of the tool by paramedics. They suggest that performance of trauma triage may be improved by involving physicians in the triage process although they do not cite any evidence for this. This study had an extremely thorough approach to data collection and completeness with cases reviewed by nurses. Where data were missing, this was followed up by telephone calls to the EMS providers. The dataset was comprised of all trauma bypass patients, and those who were transferred to a trauma centre, including children. Despite the high quality data collection, analysis was limited and findings were very specific to the local area with little transferability.

Tamim et al. (2002) noted poor clinician compliance with use of their tool but it is not clear why this was although it was studied around the time of its implementation and so may have indicated a resistance to new practices. Voskens et al. (2018) calculated a compliance with the protocol by EMS staff as 72.6%. This study used the same data set as van Rein et al. (2019), which was obtained from prospectively collected EMS reports, to which triage criteria were retrospectively applied. Missing data were addressed by imputation carried out by a software solution.

A number of studies (Brown et al., 2011, Lin et al., 2012, Newgard et al., 2011b) considered triage criteria that included ‘EMS provider judgement’ or ‘high index of suspicion’ within the triage tools. This describes the perception by a clinician on scene that a patient may be severely injured, even if they cannot objectively quantify the rationale for this judgement. Lin et al. (2012) found that this was the most frequently utilised criteria for ’triggering’ the triage tool, used in 36.9% of cases. In this study, the use of this criteria was associated with an over-triage rate of 78.8%. However, this was a small study with numbers of many types of injury being too small to provide meaningful analysis. When a pre-hospital clinician solely uses the clinician judgement criterion to identify that a patient has severe injuries, it suggests that none of the other physiological or anatomical elements were ‘positive’. It would appear then that it is used to supersede the findings of the tool when the paramedic or Emergency Medical Technician does not feel confident with

the triage outcome suggested by the trauma tool. Newgard et al. (2011b) however found that 'EMS provider judgement' was a high predictor of serious injury but no data are provided with regards to over-triage relating to this element of the tool. When subjective elements such as this exist, the triage tool becomes much more flexible as there always exists an opportunity to alter the outcome by deploying this criterion. Therefore, the objective criteria hold less value than in a tool that does not offer clinicians an opportunity to override it. This could lead to huge alterations in the sensitivity and a specificity of the tool, dependent on operator.

Voskens et al. (2018) found that although their triage protocol performed badly with an under-triage rate of 64%, in practice, this was overridden by EMS provider judgement and the actual rate of patients under-triaged and not transported to a Level I centre was 22%. However, they acknowledge that they cannot identify any confounding factors such as clinician and patient preference for a particular hospital. None of the papers included in this review provide further insight as to why clinicians may or may not have concurred with the outcome of these decision-support tools. This is an important area for additional work to be carried out. All of these studies were conducted by hospital-based staff with clinical input from physicians. There is scope for further work to be conducted with EMS providers in order to better understand the issues that relate to their use of the available trauma triage tools.

Under-triage was found to be more prevalent in patients brought in by paramedics than when an anaesthetist was on scene in a Norwegian study (Rehn et al., 2009) although the physician staffed units were more selectively tasked to incidents which were initially assessed as high acuity.

EMT judgement as a means of accurately identifying severely injured patients was specifically evaluated by Lavoie et al. (2010). Quality improvement activity in their trauma system which was concurrent to the study led to a compliance to the triage protocol of 90% by EMS providers. Although the best single predictor of severe trauma was EMS judgement, even with this included in their triage protocol, they failed to achieve sensitivity rates above 85%.

2.7 Under and over-triage

Macken and Manovel (2005) comment that over-triage is a concern for hospitals and not patients and that it may be a political rather than a medical issue. The ideal

TUB tool would have a high sensitivity and a high positive predictive value although a clear trade-off exists between these two factors (Macken and Manovel, 2005). Kane et al. (1985) reported that to obtain a sensitivity of greater than 80%, they were unable to maintain an over-triage rate below 70%. Tamim et al. (2002), when discussing this relationship, noted that when time-independent variables (e.g. age, mechanism of injury, body region injured) were included in a field triage tool, sensitivity was increased but at the expense of specificity. The American College of Surgeons (2014) suggest that an over triage rate of 50% may be acceptable but this is not supported by any scientific evidence (Dehli et al., 2016).

Under-triage was found to be highest in elderly patients by Voskens et al. (2018) with a rate of 39% compared to 14% in adults under 65 years of age. Age was significantly associated with over-triage in a Norwegian study by Rehn et al (2009). Interestingly, this study also reported that the rate of under-triage was higher for female patients than in male patients although their study population was majority male (75%). However, this difference lost its significance when adjusted for age as the female group tended to be older. The prevalence of female patients in the under-triaged group correlated with findings by Dinh et al. (2012) in Australia but this may also be confounded by age.

Interestingly, under-triage may be more significant in some groups of patients. For example, Bouzat et al. (2015) discuss patients with an open leg fracture and an asymptomatic pneumothorax who, despite having an ISS of 18, may be appropriately treated in a lower level trauma facility, particularly if surgical intervention is not required. However, those with head injuries requiring neurosurgical intervention, must be transported to a hospital were this can be provided rapidly (Voskens et al., 2018).

A large systematic review of papers which investigated under and over-triage found that even studies which assessed the same protocol showed large differences in under triage (van Rein et al., 2018a). This would imply that there are variables within each setting which alter the performance of a triage tool. Ocak et al. (2009) found that the ACS-COT tool performed differently in their setting in the Netherlands to when it was tested in the United States (Newgard et al., 2011b) although the Dutch study was very small compared to the American one which was a large multisite study.

Patients subject to under triage in the Rehn et al. (2009) study had significantly higher mortality risk compared to those who were accurately triaged. They do not evaluate the potential reasons for this but it may be that if injuries are unrecognised in the field, they are not then identified initially in the hospital or the index of suspicion for severe injury is low. This could lead to delays in imaging and therefore definitive management.

2.8 Summary of performance of trauma triage tools

The main findings in terms of the performance of each trauma triage tool are described in the summary of the 22 papers reviewed (Table 2-3). Dehli et al. (2016) evaluated a trauma protocol which had been altered subsequent to a previous study (Rehn et al., 2009). They found no improvement in the tool in terms of rates of under and over-triage. This highlights the benefits of modelling a proposed new tool rather than introducing it and then re-testing it. Nowakowski et al. (2019) took this approach when they compared the accuracy of the American guidelines for field triage to their own Polish criteria. The alteration in accuracy of predicting ISS>15 was huge with sensitivity increasing from 18% to 91.5% in the same data set. Changes in practice can be difficult to implement due to staff training, changes to recording systems (electronic or paper-based), issues around ongoing data collection and practical roll-out of a process. Therefore, it would seem sensible to test a new tool prior to it being introduced into practice, as is suggested in this project.

One of the problems with accurate triage of patients in the field is that symptoms may evolve with time and transport decisions are often made early on in the care of the patient (Rehn et al., 2009). Ocak et al. (2009) utilised the physiological parameters which were first recorded on the paramedics arrival at scene. There may be confusion at scene as to whether this should be the case or whether physiological findings after resuscitation should be utilised. For example, the Wessex TUB specifically requires ‘sustained respiratory rate’ to be deranged for a positive result.

The findings from Rehn et al. (2009) led them to recommend that they should implement a two-tiered response to trauma in their hospital. This is similar to the trauma team activation currently in place at UHS. They also felt that trauma team activation could be improved by greater communication from the scene by

paramedics to the trauma nurse co-ordinator in the hospital. The role of communication, human factors and other non-technical skills is increasingly viewed as being an essential component of trauma systems and trauma education and courses such as the European Trauma Course are adopting this into their curriculums (Thies et al., 2013).

All of the papers address the trade-off between under-triage and over-triage (2.7). The former is seen as a patient issue, and can result in care failures or delays. The latter is a systems issue and may have an impact on efficiency and availability of specialist services. The Newgard et al. study (2011b) suggest that the reduction in specificity required to achieve sensitivity of a tool of 95% may not be sustainable for major trauma centres. They advise revising this goal to 90%.

2.9 Recent publications and research

2.9.1 Additional literature search

The literature search for this study was initially completed at the end of 2018 and repeated in 2021. Towards the end of preparation of a full draft thesis, a meta-analysis was published (Gianola et al., 2021) which is discussed below. In addition, a large NIHR-funded study is currently under way in the UK – the Major Trauma Triage Tool Study (MATTS) project (University of Sheffield, 2019). Both of these studies are significant, the first due to the breadth of its analysis and relevance to this thesis, and the second as it not only recognises the current situation in the UK, as outlined in 1.4, but has significant funding to make improvements to clinical practice.

Gianola et al. (2021) published a piece of work carried out to support the development of national major trauma guidelines in Italy. This study was substantial in scale, with a large number of authors and support from the Italian National Institute of Health. They searched Medline, Embase and Cochrane for papers available up until November 2019. A wide range of search terms were selected to encompass the whole trauma population and initially screened 7,285 records, resulting in 15 papers being selected for evaluation. Their research question was

> *"Are the pre-hospital triage tools accurate in predicting adequate destination of severely injured patients to a trauma centre?"*

The study aimed to use the same methodology and search criteria as that employed by NICE in preparation of the Major Trauma: service delivery guideline – NG40 (2016c).

As expected, and in common with the findings of the literature review presented in this chapter, the ACS-COT tool was utilised in multiple papers (6 studies in adults). The cumulative results for this tool in predicting ISS>15 was sensitivity of 79% and specificity of 76%. They also presented results for MGAP, NTS, T-RTS, GAP and Vittel Triage Criteria although the latter was only included in a qualitative study as there were no overall values of sensitivity and specificity for this tool.

In addition to using ISS>15 as a reference test, they also included mortality, survival, and admission to intensive care where this had been reported. The tool which was found to most accurately predict ISS>15 was the TRENAU tool evaluated by Bouzat (2015).

The Wessex TUB tool is included in the Gianola et al. (2021) review as it had been evaluated in a study by Cheung et al. (2013). However, it was only considered for use in children, with a sensitivity of 77% and specificity of 47%. Overall, this systematic review found high variability in accuracy of triage tools and a variety of reference standards used which concurs with the findings of the literature review described in this chapter. It also recognised the need for a well-performing tool in order to maximise healthcare system effectiveness and minimise costs.

2.9.2 MATTS Project

The Major Trauma Triage Study (MATTS) is a National Institute for Health and Care Research (NIHR) study currently being carried out at the University of Sheffield. It is a large programme of research which is investigating trauma triage tools in use in NHS major trauma networks. Its aim is:

> *"to develop an accurate, acceptable and usable pre-hospital triage tool to identify patients with major trauma benefiting from MTC care."*

The study consists of three phases :

1. triage tool identification and development
2. validation study
3. evaluation of system-level performance of implemented optimal triage tool

At the time of thesis submission, the output from this group has included an investigation into the accuracy of prehospital triage tools in identifying major trauma in the elderly (Fuller et al., 2021b), an economic evaluation (Pollard et al., 2021) which is in preprint and utilised data from the Newgard et al. study (2013a) and a validation of a Dutch triage tool in a UK population (Shanahan et al., 2021). The work from this study has also been presented at conferences, including a systematic review of currently available triage tools (Holt et al., 2020) which categorised the most common variables found in these tools into 5 major groups. Several ambulance services in England are included in this work and are currently trialling modifications to their trauma triage tools. At the time of writing, this work is still ongoing, with the main findings yet to be reported, and modifications to the tools still being tested.

2.10 Summary of the review of the literature

A summary of the papers reviewed is presented in Table 2-3. A range of literature was evaluated with the majority originating from the USA and Australia. This is concordant with the discussion in 1.3.3. Although the papers represented international practice, no UK paper has fully evaluated a trauma unit bypass tool, demonstrating the need for this work to take place in this country.

Issues around data completeness were addressed in a variety of ways (2.2.4). There was a benefit to conducting prospective studies in achieving this, however, this can be very resource intensive. Most studies utilised trauma registries (similar to TARN) to provide data for analysis.

Most of the studies used ISS as a measure of major trauma, although additional outcomes were combined with this in some papers (2.5). There is various rationale for this and so outcome measures should be justifiable in the context of the research setting. Whilst most tools utilised anatomical, physiological and mechanism of injury variables, some also included an opportunity for a clinician to use their discretion to triage to a high-level centre (2.6). The efficacy of this varied across studies.

The accuracy of triage tools in predicting major trauma varied, even when the same tool was evaluated in different settings (2.7). A trade-off between under- and over-triage was widely considered. The need for research into this area is

demonstrated by the number of large-scale studies being carried out internationally in this field and the addition of a recent UK NIHR funded project.

All of the studies described in this chapter were conducted by hospital staff, with input from physicians. There was an opportunity identified for a study to be carried out by a paramedic researcher with experience in pre-hospital trauma triage as described in 1.3.3. This may provide additional insight and experience, in the context of a professional doctorate.

Chapter 3 Methods

3.1 Introduction

This chapter describes the study methodology and the key considerations and decisions that were made in order to ensure rigour, within the constraints of a project of this size. It outlines the study design, including rationale for this, and outcome measures used. Detail is provided around the collection and handling of data, including missing values and interpretation of free text. The data analysis and application of statistical tests are then presented in detail, followed by the means by which results were compared with other triage tools. Finally, adjustments to the tool are described and how these were analysed to provide comparative results.

3.2 Research design

3.2.1 Study design

The terms ‘prospective’ and retrospective’ refer to the timing of the research in relation to the development of the outcome, i.e. in retrospective studies the outcome of interest has already taken place by the time the patient is enrolled into the study (Ranganathan and Aggarwal, 2018). In health care, this methodology is also known as ‘chart review’ because the data source is the medical record (Hess, 2004).

This doctoral study is a retrospective analysis of data collected from multiple sources. The benefits and challenges of a prospective study were discussed in 2.2.4. As this study was undertaken towards an academic award, there was no funding or organisational support to enable a prospective study to be performed. This would have had the benefit of being able to collect any data fields which may aid in answering the question and would likely result in greater data completeness but would require resource not available to this study. However, a benefit to the retrospective methodology is that outcome or recorded information cannot be, either deliberately or inadvertently, altered due to the simple fact of the study occurring and clinicians being aware of measurements and recording.

Retrospective designs are typical in studies of this nature and form the majority of the evidence base evaluated in the literature review (Chapter 2) (Cox et al., 2011, Cox et al., 2012, Dinh et al., 2014, Macken and Manovel, 2005, Lavoie et al., 2010,

Tamim et al., 2002, Bouzat et al., 2015, Ocak et al., 2009, Rehn et al., 2009, Brown et al., 2011, Henry, 2006).

Testing methods for decision support systems are discussed by Lamy et al. (2010) as necessary for assessing the validity of tools used in clinical practice. Failure to adequately evaluate such diagnostic aids can result in outputs of uncertain quality (Sailors et al., 1996). Dynamic methods of testing describes the empirical evaluation of a tool against test cases, with a preference for real scenarios to be in the test base. A limitation of this method, in common with any quantitative study, can be missing values and so care must be taken to ensure that all the required information is present. The ability to access individual case notes in this study ensured that data missing from initial sources was obtained at a later stage, resulting in a high level of data completeness.

Validation should also examine whether the tool is realistic and useful to the clinician who will use the tool in practice to ensure it is fit for purpose (Sojda, 2007). The usability of the TUB tool is out with the scope of this study and would require a mixed methods approach to evaluating the tool. However, a small study has assessed the use of the smartphone application version of the Wessex TUB tool in comparison to the original paper-based format (Freshwater and Crouch, 2015).

A comment piece by the validity theory researcher Sireci (2016) concludes that

> *"if the use of a test is to be defensible for a particular purpose, sufficient evidence must be put forward to defend the use of the test for that purpose".*

Much of the literature around validity testing relates to educational theory. It is also utilised in evaluating decision support tools in clinical practice, although mainly with regards patient-observed tests such as quality of life measurements or assessments for mental illness. Some general concepts may be gleaned though from academics in this area such as (Hubley and Zumbo, 2011, Messick, 1998) in that validating a test has consequences in respect of the outcomes of its use. For example, in this doctoral study the consequences of using the tool could result in variation of treatment centre for a patient who has sustained a traumatic injury.

The quality of decision making that is influenced by a diagnostic decision support tool is discussed by Ramnarayan et al (2003), in a study from an acute medical setting. However, this focuses on the end users of the product rather than the tool itself. A paper relevant to this study (Twomey et al., 2007) defines validity as

> *"the degree with which the measured acuity level reflects the patient's true acuity at the time of triage."*

It goes on to discuss one of the limitations of evaluating triage tools against true acuity is that many factors may alter the management of that patient from first contact until discharge. For example, the recognition of injuries can be affected by time from injury to receiving care, imaging and diagnostics performed, communication challenges with patients and concordance with treatment. Using ISS greater than or less than 15 as a measure of acuity is flawed as ISS does not refer to how unwell the patient was when they received care, for example how low their blood pressure was or if organs were being perfused. Two patients may have very similar injuries but for various reasons, respond differently both to the insult and also to the treatment provided. For example, a patient could sustain multiple rib fractures but compensate well due to their general health, whereas another patient with similar injuries could go on to develop an infection or acute respiratory distress syndrome (ARDS) and require intensive care support. Therefore, as discussed in 3.3, ISS is not the only measure that could be considered when evaluating the need for specialist trauma care.

Streiner and Norman (2006) discuss the difficulty of validity testing of tools used in healthcare as they are attempting to measure 'softer' domains such as pain, functional limitations, quality of life and so on. However, where there is a 'gold standard' against which to measure results, such as comparing imaging to biopsy, criterion validity can appropriately and successfully utilised. This highlights the benefit of selecting a quantitative measure, such as ISS>15, as an outcome meaure.

Seminal work by Messick (1995) considers the wider contextualisation of validity with reference to the use of tests in practice. He states that

> *"validity is not a property of the test or assessment as such, but rather of the meaning of the test scores……what needs to be valid is the meaning or interpretation of the score; as well as any implications for action that this meaning entails."*

Whilst this work primarily relates to educational testing, it has been translated to healthcare settings by others (Streiner and Norman, 2006, Twomey et al., 2007). The former paper proposes that validity and accuracy are not interchangeable

terms with ‘accuracy’ having arisen from studies in clinical laboratories. However, for the purpose of this study, and readability, the term accuracy is also used when discussing the performance of the TUB tool in predicting major trauma.

Reliability and validity are interconnected concepts (Zumbo, 2006) and must both be assessed in the evaluation of a triage tool (Twomey et al., 2007). Reliability refers to the ability of a tool to produce the same result when repeated assessments are carried out with the same patient and inter-rater reliability is the ability of the tool to perform in this manner with a variety of users (Twomey et al., 2007). Whilst assessing reliability is important, it is outside of the scope of this project. It could be carried out either with fabricated test cases or real patient cases. If this were to be undertaken in clinical practice, it is likely that a prospective study with high resourcing requirements would be needed in order to test the assumption that two people assessed the same patient and that accurate results were recorded. If testing were undertaken in a simulated environment, this would likely be a more accessible study to undertake, and it has some benefits and limitations. Simulated patients can have ‘fixed’ observations which are controlled by the operator running the simulation and there would be no extraneous clues as to the severity of the patient’s injuries. This would ensure consistency in the patient’s presentation between triage tool operators. However, it is very difficult to accurately simulate injuries such as a flail chest or paralysis.

In summary, partly for practical and resource reasons, a retrospective design has been selected. However, this allows comparison with an outcome measure which is calculated once a patient has been discharged. This type of study design has the potential to have high data loss, although this has been mitigated by having access to clinical notes to augment data collected in a database. The selection of binary test results (TUB positive or TUB negative) with a quantitative outcome measure allows accuracy testing of the TUB tool to take place.

3.3 Definition of Major Trauma

As described in the review of the literature (2.5), to calculate the sensitivity and specificity of a tool, first it is necessary to define what is meant by 'major trauma'. The most widely adopted definition employs the Injury Severity Score (ISS) (de Jongh *et al.,* 2010). The ISS is an anatomical scoring system, developed by a team at John Hopkins University, Baltimore over forty years ago (Baker *et al.*, 1974) and

is the oldest and best-known summary score derived from the Abbreviated Injury Scale (AIS) (Palmer et al., 2016).

An explanation of the calculations used is provided by The Trauma Audit and Research Network (TARN) as follows:

> *"All injuries are assigned an Abbreviated Injury Scale (AIS) code and score from an internationally recognised dictionary that describes over 2000 injuries and ranges from 1 (minor injury) to 6 (an injury that is thought to be 'incompatible with life'). Patients with multiple injuries are scored by adding together the squares of the three highest AIS scores in three predetermined regions of the body. This is the ISS which can range from 1 to 75. Scores of 7 and 15 are unattainable because these figures cannot be obtained from summing squares. The maximum score is 75 ($5^2+5^2+5^2$). By convention, a patient with an AIS6 in one body region is given an ISS of 75. The injury severity score is non-linear and there is pronounced variation in the frequency of different scores; 9 and 16 are common, 14 and 22 unusual. The assignment of AIS codes and scores are undertaken by trained coders within a Quality Assurance programme."*

The ISS can only be calculated once imaging and investigations have been carried out and therefore it is not of use as a triage tool itself.

As part of data submission for TARN (1.2.3), ISS is calculated by a trained coder. In order to be included on this trauma registry, a patient must meet a number of criteria as outlined in Table 3-1.

Table 3-1 TARN eligibility

Hospital admission for longer than 72 hours **OR**
Critical care admission **OR**
Transfer to a tertiary/specialist hospital **OR**
Death within 30 days **OR**
AND
Isolated injuries meet specified criteria

However, some patients who are TARN eligible have relatively minor injuries which are unlikely to benefit from specialist major trauma centres (Moran et al., 2018). An ISS of greater than 15 has been the most commonly used threshold for defining major trauma since the 1980s (Palmer et al., 2016), however, this threshold is arbitrary (Palmer, 2007). All bar one study from the review of the literature elected to utilise an ISS of greater than 15 for at least part of their definition of major trauma. Therefore, this in combination with its use as a means of differentiating payment levels for Best Practice Tariff is why ISS>15 was selected for this study as the definition of major trauma. This is also the measure used in the Wessex Trauma Network when evaluating secondary transfers from a TU to an MTC (which may have been incorrectly triaged from scene).

3.4 Ethical approval

As discussed in 1.3.3, there are many challenges around conducting ethical research on patients in the pre-hospital and emergency phases of care. Although many of the patients whose records were accessed for this study will have been inpatients in the hospital, it is likely that a significant proportion will have been discharged directly from the Emergency Department. Therefore, the only common location in the hospital which all patients will have been treated was the ED, producing challenges in providing information to patients about this study. Whilst inpatients are generally seen by a Major Trauma Nurse Co-ordinator (MTNC) who will be able to explain any queries a patient or their family may have around participation in research (Crouch et al., 2015) the group who do not make it to the ward areas will not have access to this. Therefore, a web-based approach to reaching out to patients was selected (Appendix B - Patient information).

Data linkage was used in this study which required patient identifiable information to be accessed (3.5). Linking of data from different sources in the healthcare system must be done ethically and securely, and in a way that is acceptable to patients (Turner et al., 2019). Data handling must meet the requirements of the Data Protection Act (Great Britain, 1998). The use of personal information must be justified and the relevant considerations given to information governance. The measures to ensure this were outlined in the Integrated Research Application System (IRAS) form and assurance of compliance is demonstrated in Appendix D.

Guidance exists from the Health Research Authority (HRA) to address the area of patient consent in research in emergency settings, although this refers to instances where immediate interventions or drug administration are required and so was not immediately applicable to this study (Health Research Authority, 2020).

3.4.1 Health Research Authority

Ethical approval for this study was sought from the National Health Service Health Research Authority (HRA) with an application made via the Integrated Research Application System (IRAS) to both the local Research Ethics Committee (REC) and the Confidentiality Advisory Group (CAG). The only concern raised at the REC meeting related to a potential scenario where the researcher may discover unsatisfactory care or negligence in the care of a patient. Most of the cases included in the data set will have been reviewed prior to submission to TARN and, as such, any issues will have already been identified and addressed. For any cases which were either not TARN eligible or omissions or errors were discovered, the researcher would escalate these through the established governance systems within UHS or the Wessex Trauma Network as appropriate.

The CAG panel had additional points of concern with regards the accessing of patient identifiable data by the researcher and the opportunity for patients to opt out of the study. Assurances were provided with regards the acquisition and storage of data by the researcher which were accepted. Further work was carried out to ensure patient engagement, through Patient and Public Involvement (PPI) representatives and details of the study being made available on the UHS and WTN websites with an email address for patients to make contact to have their details removed from the study. A post was also made on a patient website (AfterTrauma.org) with similar information (Appendix B). During the period of the study and compilation of this thesis, no emails had been received. It was not envisaged that large numbers of patients would withdraw their consent as this is a retrospective case review and so there would be no change to the treatment they received for their injuries. Clearly, if there had been large-scale removal of cases, this would have affected the data sampling and may have introduced unintended biases. HRA approval was granted and a copy of the letter received appears in Appendix D.

3.4.2 Other approvals

In order to undertake this research as part of a postgraduate degree, ethical approval was also required from the University of Southampton. Approval was granted as detailed in Appendix E.

The final governance and research approval required was from the University Hospital Southampton, as the study involved their patients, and to ensure there was capacity within the Trust to undertake this work. This was granted once HRA approval was assured. Details of this approval are provided in Appendix F.

3.5 Data Collection

The TARN dataset was reviewed to evaluate the required fields for this study. A request was made, via the UHS TARN administrator, for data covering a period from 1st September 2016 to 31st August 2017. This time period was selected to avoid any effect of seasonal variation being introduced. The required fields were specified and provided to the UHS TARN Manager. Data were received via an Excel spreadsheet which was emailed to a secure nhs.net email account by the TARN administrator in UHS. The TARN database provided 1086 cases of patients who were TARN eligible and admitted via the Emergency Department during the period selected for the study. This number of cases (n=1086) represents all patients entered onto TARN during the study period who arrived in the hospital via ED.

A search was performed on the ED patient record and administration system (Symphony) to find all patients booked in with ‘major trauma’ as a presenting complaint who were first assessed in the Resuscitation room of the Emergency Department during the same time period. This was performed by one of the UHS data analysts. This search identified records for 707 patients. This piece of software allows export to Microsoft Excel and so the records were converted to a spreadsheet format and again emailed via secure email. These cases (n=707) represent all major trauma patients who were received in the resuscitation room of the ED during the study period, and therefore presumed to be potentially seriously injured and require immediate assessment.

Both of these spreadsheets contained NHS numbers and hospital numbers. Some cases were missing one of these, but all cases had at least one unique identifier

present. This enabled merging of the data sets (performed on 22nd January 2018) and removal of duplicates as some patients could appear in both data sets. A total of 1252 cases remained. Whilst this was in part a convenience sample based on one full year, the number of cases to be reviewed had to be achievable with the resources available to this study, being carried out by a single researcher. Many of the studies described in the review of the literature (Chapter 2) contain many tens of thousands of cases, but this was not feasible for this doctoral study. This is largely due to the study design as, to ensure data completeness and inclusion of all relevant patients, significant time was required to conduct case review. However, the previous evaluation of sensitivity of the Wessex TUB tool (Potter et al., 2013) only contained 175 patients and so this study is likely to provide greater accuracy in evaluating the same tool.

Table 3-2 shows the type of data contained in each field collected, and which source it was obtained from. Some fields were unique, and others were available from both TARN and ED data.

Table 3-2 Location of individual data fields

Data field	Type of data	TARN	ED records
TARN submission ID	Unique ID number		
Hospital number	Unique ID number		
NHS number	Unique ID number		
Sex	Categorical		
Age	Continuous		
Arrival date	Continuous		
Arrival time	Continuous – 24-hour clock		
Incident date	Continuous		
Incident time	Continuous – 24-hour clock		
Incident postcode	String – UK postcode		
Incident location	e.g. home, public area		
Incident description	Free text		

Data field	Type of data	TARN	ED records
Triage tool	Categorical - ‘Positive’, ‘negative’ or ‘not recorded’	■	
Triage comments	Free text		■
Discharge destination	Categorical – e.g. ITU, inpatient ward, home, mortuary		■
Injury type	Binary - Blunt or penetrating	■	
Mechanism	Categorical – e.g. fall less than 2m	■	
Injury intent	Categorical	■	
Pre-hospital GCS (also broken down into components)	Ordinal	■	
Pre-hospital oxygen saturations	Continuous	■	
Pre-hospital pulse rate	Continuous	■	
Pre-hospital respiratory rate	Continuous	■	
Pre-hospital systolic blood pressure	Continuous	■	
ED GCS (also broken down into components)	Ordinal	■	■
ED Oxygen saturations	Continuous	■	■
ED pulse rate	Continuous	■	■
ED respiratory rate	Continuous	■	■
ED systolic blood pressure	Continuous	■	■
ED temperature	Continuous	■	
MEWS score	Continuous - Modified Early Warning Score		■
ISS	Continuous	■	
Injuries	Free text	■	

One of the main strengths of this study is that it contains not only TARN data, but data for all patients who were brought to ED with suspected major trauma. The

addition of patients from the ED system ensures the inclusion of cases where major trauma may have been suspected but was later found to not be present.

3.5.1 Case inclusion

Each individual case from the resulting data set was then reviewed to assess its appropriateness for inclusion. As this study is only concerned with patients assessed at the scene of their injuries by emergency services, any patients who did not fall into this category (e.g. injured abroad and then presented having received treatment overseas) were excluded.

Some patients (n=20) included in the data set did not present to the emergency services and were therefore excluded (Figure 3-1). This information was either recorded on the TARN database or was apparent from Symphony where one of the initial triage questions identifies if patients arrived by ambulance. Also, information was available where the ambulance transport had been a secondary transfer from another healthcare facility. Southampton is unusual in that it has a busy cruise ship terminal and so some patients were injured aboard ship (n=9), cared for by onboard medics and then transferred to UHS upon arrival at shore. Other patients initially presented to their General Practitioner (GP) or a Minor Injury Unit (MIU) and were subsequently referred to the Emergency Department. These patients were removed from the dataset as they were not assessed by ambulance clinicians at the time of their injury and would not have any record of their observations at this time and so the TUB tool could not be accurately applied to them.

In addition, patients who were brought to hospital more than one day after their injury (n=42) were excluded as the recorded physiology would not have been taken at the time of injury. It is possible that patients who initially felt their injuries were minor either experienced increased pain or sought advice which subsequently resulted in an ED attendance.

Of the patients who self-presented either at ED or an alternative facility, it is probable that their injuries appeared minor in the first instance and it is likely that they were fully conscious and able to walk. This is a self-selecting cohort of patients as they may not have felt their injuries warranted calling 999 for assistance.

Of some concern is the cohort of patients who were discharged (n=13), either from UHS or another ED, who then re-presented with their injuries. This raises questions

about the initial assessment, appropriate imaging of injured areas and periods of observation for patients involved in trauma. Although it is out with the scope of this study, it would be interesting to investigate this cohort further in order to make improvements in care for the future. However, it may demonstrate that in fact appropriate ‘safety-netting’ practices are effective and result in patients whose injuries later become apparent, presenting for further assistance.

Patients who suffered isolated burn injuries (n=5) (i.e. not in conjunction with a traumatic injury) were also excluded as they are managed through the South West Burns Network rather than the Wessex Major Trauma Network.

Once all of these excluded records (n=142) were removed, 1110 cases remained for analysis (Figure 3-1).

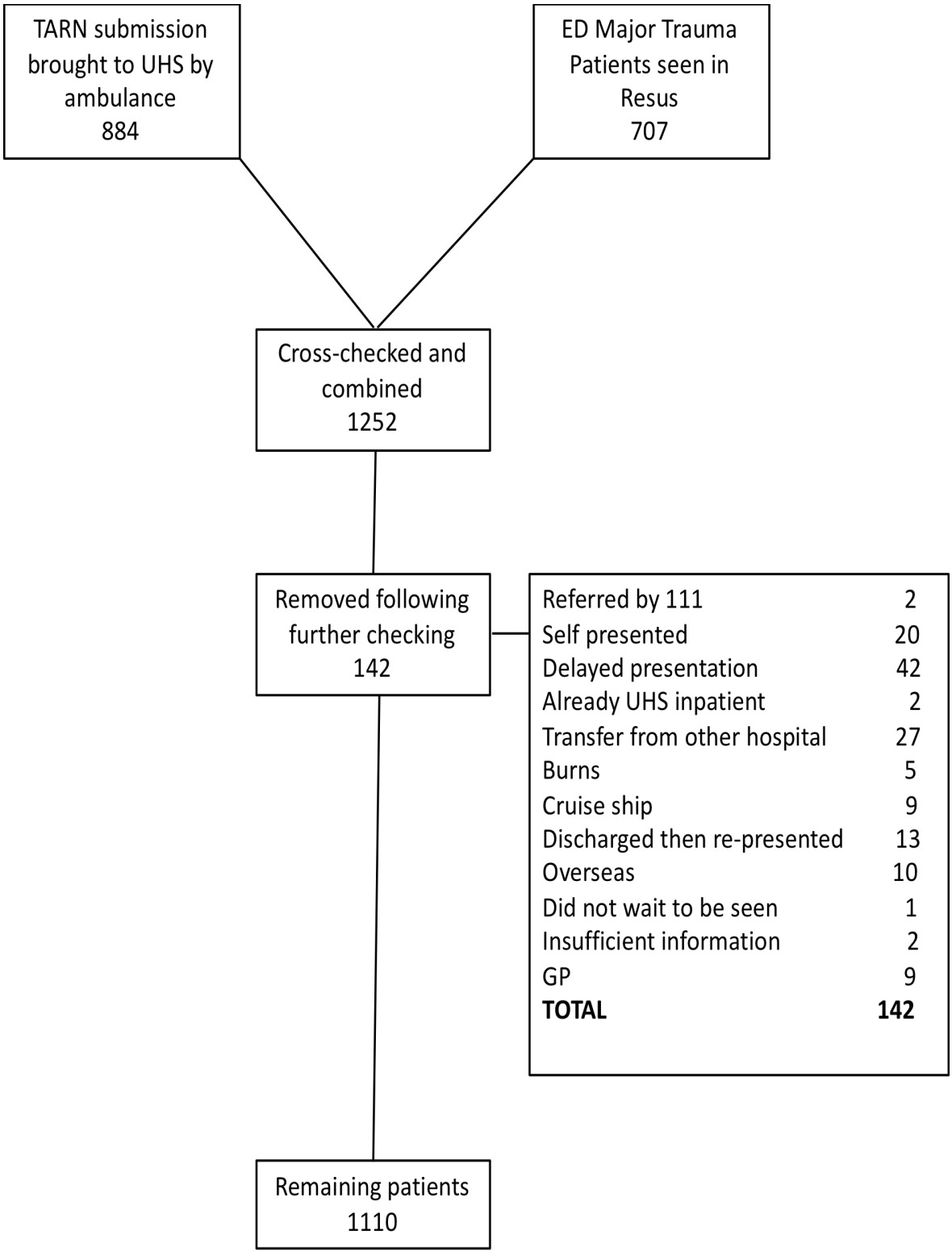


Figure 3-1 Summary of case inclusion

During the analysis of data, paediatric cases were evaluated independently. The small number of cases of children (n=75) gave rise to very wide 95% confidence intervals. The varying physiological TUB tool criteria which alter by age, meant that no meaningful statistical analysis could be performed on this cohort. In addition, the varied physiology was affecting the statistical analysis and so a decision was made to remove these cases from further evaluation. As highlighted previously, work is

required in this area to improve identification of major trauma in the paediatric population, but it is likely that a multi-centre approach would be required in order to gain a sufficient number of cases.

The final data set for full analysis contained 1035 individual cases of patients aged 16 years or over.

3.5.2 Data preparation

There were very few cases that had all data fields complete. For the ED system, Symphony, the settings require a patient's triage details to be completed before notes can be printed off. Observation in practice has identified that sometimes this section of data entry is skipped to expediate printing of materials required by the clinical staff. This can mean that pre-hospital observations are not recorded on Symphony. For example, in 160 of 707 case records obtained via this software, the initial blood pressure value was missing. This information was available on the observation chart or pre-hospital patient report form which had been scanned to the patient record. The completion of missing physiological observation data was completed by means of chart review and then entering this into the master data sheet. This was facilitated via the use of a data collection proforma (Appendix C). This form was designed prior to receipt of the data from TARN and Symphony and therefore contained data fields which were not collected as they were either not available or not reliably completed in clinical notes (e.g. level of crew attending).

On the TARN data set, pre-hospital observations were frequently missing. For example, in 711 of 1086 cases, the total GCS score (out of 15) was present but the broken-down score (eyes, verbal motor) was not inputted. This would mean that it would not be possible to indicate if the TUB was positive due to GCS motor score of 4 or less. Again, these values were obtained from manual evaluation of patient notes.

3.5.3 Missing data

3.5.3.1 Physiological data

The following approach was taken to missing physiological data:

Step 1 – manual scanning of patient's notes on CHARTS electronic system (the UHS patient documentation repository). If the data were present in the pre-hospital notes, this was completed on the data entry Excel spreadsheet.

Step 2 – if the pre-hospital notes were missing from CHARTS, a check was made to ascertain if the information entered on Symphony was the first set of observations. If so, this value was taken as the closest in time to when the pre-hospital clinicians would have used the TUB.

Step 3 – if the information was not entered into the Symphony triage section, it was taken from the scanned in observation chart, using the first recorded set of physiological observations.

This approach provided the following information for all cases:

- Systolic blood pressure
- Respiratory rate
- Glasgow coma score
- Heart rate (this is not a physiological criteria on the TUB, however, it is usually collected and reliably measured and so it was collected for all cases. This would allow it to be used in refining the tool if necessary later in the study.)

The data completeness achieved through this approach is a significant strength of this study, resulting in no cases lost to missing data.

Oxygen saturations were present for many patients but accounted for a large amount of missing data. These were not collected for all patients as their utility is questionable. Pulse oximetry readings can be affected by poor perfusion and cold peripheries, both common in trauma patients in the pre-hospital environment (Jobran, 1999). As this variable is not included in the TUB tool, it was not utilised in assessing accuracy. However, it was included in the analysis of individual variables to understand if it had any validity in predicting major trauma (5.8.2).

3.5.3.2 Anatomical data

An assumption was made that all significant injuries could be identified at the scene. Whilst this is of course not necessarily the case, a uniform approach had to be taken in order to handle all data equally. The anatomical injuries which are TUB tool criteria would usually be expected to be identified on examination, although this would not always be the case. For example, clinicians will use a combination of means to assess the patient including mechanism of injury, clinical examination and physiological findings. For example, it may not be possible to identify a flail segment (two or more rib fractures in two or more contiguous ribs), particularly if it lies posteriorly and the patient is being managed supine. The TUB tool describes 'suspected major pelvic fracture' but there is not an agreed definition for 'major' in this instance. This has highlighted some instances of lack of clarity in the terminology used in the TUB tool and this would warrant further investigation and refinement in future work.

- Open pneumothorax or flail chest – if this was identified at any point in the patient pre- or in-hospital phase (including via computed tomography), it was classed as present.

- Crushed, degloved or mangled limb - isolated digits were excluded. If any terminology was suggestive of this, it was classed as present. On occasion, the mechanism of injury would be utilised in conjunction with the injuries, for example 'crushed by machinery, fracture of tibia and fibula'. This information was usually included in the TARN injury narrative.

- Suspected major pelvic fracture – isolated pubic rami fractures were excluded as these are often stable and are managed conservatively (Studer et al., 2013).

- Neck or back injury with paralysis – paralysis is documented on TARN and all of these patients would be TARN eligible.

- >1 fractured proximal long bone – included femur, tibia and humerus fractures where more than one of these bones was broken (could be one of each or two of same type of bone).

- Amputated limb – isolated digits were excluded.

- Suspected open or depressed skull fracture – these were identified generally following CT and so available for all cases where they were present.

Additional injuries (e.g. burns, asphyxia) were also collected at this stage to assist, if necessary, with refinement of the tool.

Once all data had been adequately completed, patient identifiers were removed, and each record assigned a unique case identifying number. A reference of case number to NHS number was stored separately on an NHS computer. No further use was made of patient identifiable data.

Where any of the physiological or anatomical criteria were met, a '1' was entered into the relevant data field and where they were absent a '0'. A total score of 1 or greater was classified as 'TUB positive' and a score of 0 as 'TUB negative'.

Basic demographic data (age and sex) were also collected for each case.

On completion of the Excel (Microsoft) spreadsheet, data were imported into SPSS (IBM) for further analysis.

3.6 Trauma Unit Bypass Tool Activation

In order to understand the performance of the TUB tool, it was necessary to create an extra field 'TUB triggered', a positive or negative response to the 'test'. In order to do this, each case was evaluated as follows:

- For TARN eligible cases, the 'Triage Tool' field was evaluated. However, the result was 'not recorded' in 721 cases. One case was identified as 'negative' and 157 cases as positive.
- For all cases, if the first set of observations met any of the physiological criteria this was considered a positive TUB tool.

For anatomical elements, cases were investigated as followed:

- Specific mention in the triage comments as this would be information handed over from the pre-hospital team to the Emergency Department (# indicates fracture). Examples include:

"fall from standing, right flail chest and surgical emphysema, head injury on apixaban" was categorised as positive for 'open pneumothorax or flail chest'

"high speed motorcycle into bus. Significant head, chest and pelvis injuries" was categorised as positive for 'suspected major pelvic fracture'

"Fallen from tree. ? spinal injury. Unable to move legs" was categorised as positive for 'neck or back injury with paralysis"

"Motorcyclist accident, 70mph. ? Bilateral tib/fib #" was categorised as positive for >1 fractured proximal long bone

- For cases where this information was not available, the scanned pre-hospital record was evaluated. If the ambulance crew had recorded any phrase which indicated trauma unit bypass had been enacted or the patient was TUB tool positive, this was recorded. In addition, if they specifically mentioned any of the anatomical injuries contained within the TUB tool, this was recorded as TUB positive.
- Where the pre-hospital notes were not available, incomplete, or did not specifically mention the injuries, for the TARN eligible patients, the 'Injuries' field was reviewed. Any injuries recorded here, which matched with the TUB tool, were considered to 'trigger' the TUB tool.
- For any cases where none of the above existed, the case was categorised as TUB tool negative.

3.7 Data analysis

Basic demographic data were analysed, using the Codebook and Descriptive Statistics functions in SPSS (IBM Corp.). Data were analysed to demonstrate the sample, including sex and age variables, and the time of day and year that the patients arrived in the ED at UHS. Further analyses described the patterns of injury sustained and the areas of the body injured, and the Injury Severity Score broken down into established categories.

3.7.1 Sensitivity and Specificity

In order to calculate sensitivity and specificity, a custom table was produced to create a 2 x 2 square, indicating TUB positive or negative and ISS > 15 (major trauma present) and ISS < 15 (major trauma absent).

Firstly, it was necessary to undertake a test of significance to evaluate if the variables are related (Hossain, 2021). The null hypotheses for the chi-square test for independence states that the two variables being measured (ISS>15 and TUB positive) are independent, in other words the value of one variable is not influenced by (or related to) the value of the other variable (Wallnau, 2017).

The data from this 2x2 table were entered into StatPages (https://statpages.info/ctab2x2.html) for analysis of sensitivity, specificity, positive predictive value and negative predictive value, as recommended by Barton and Peat (2014). These diagnostic statistics were provided, along with 95% confidence intervals.

The following terms were described (also summarised in 1.5.1):

True Positive (TP) – the test correctly identifies that major trauma is present

False Positive (FP) – non-major trauma patients who had a positive test

True Negative (TN) – patients without major trauma who tested negative

False Negative (FN) – patients with a negative test who had suffered major trauma

Sensitivity is calculated using the following equation:

$$Sensitivity = \frac{TP}{TP + FN}$$

Specificity is calculated with:

$$Specificity = \frac{TN}{TN + FP}$$

From these analyses, it was possible to identify each case as under-triaged (TUB negative with an ISS higher than 15), correctly triaged (i.e. true positive or true negative) and over-triaged (TUB positive but ISS less than 15). Further demographic data were used to describe each of these subsets, including mean and median age. The mean describes the average and is calculated by the sum of all values, divided by the number of values. The median describes the mid-point of all values when the data are arranged in numerical order. Both mean and median were calculated to allow comparison with other studies as both were used.

The frequency with which each component of the TUB tool was activated was recorded. This was described in both the under- and over-65s as well as overall and, for those cases where more than one component of the TUB was positive, how many variables were positive. For example, if a patient had a systolic BP of less than 90 and an amputated limb, they would score 2.

3.7.2 Positive and negative predictive value

Positive predictive value (PPV) is defined as the probability of the disease (major trauma) being present in a positive test and negative predictive values (NPV) is the probability of disease not being present in a negative result (Mandrekar, 2010, Pallant, 2016, Bruce et al., 2018). The PPV and NPV require the prevalence of disease in the studied community to be known (Peat et al., 2001, Katz, 2001).

Using the definitions in 3.7.1, these are calculated as follows:

Positive Predictive Value

$$PPV = \frac{TP}{TP + FP}$$

Negative Predictive Value

$$NPV = \frac{TN}{TN + FN}$$

The main difference between sensitivity and specificity and PPV and NPV is that the latter uses the prevalence of a condition to determine the likelihood of a test diagnosing that specific disease. Sensitivity and specificity describe the validity of a test in correctly identifying a patient as having, or not having, a disease. PPV and NPV report the percentage of patients with a positive, or negative, test who do or do not have the disease. Both can be used by clinicians when deciding to apply a test to a patient with the intention of ruling-in or ruling-out a condition.

3.7.2 Likelihood Ratio

Likelihood ratio (LR) can be used independently of disease prevalence. Sensitivity and specificity can be combined into a single index as a LR as shown below (Mandrekar, 2010).

Positive Likelihood Ratio

$$LR+= \frac{sensitivity}{(1-specificity)}$$

Negative Likelihood Ratio

$$LR-= \frac{(1-sensitivity)}{specificity}$$

This test provides the same information as sensitivity and specificity but combines it into a single value which describes the probability of a positive or negative test result in a diseased person compared to a healthy person (Hossain, 2021).

3.7.3 Diagnostic odds ratio

This outcome is derived from logistic methods and can be valuable in comparing the performance of various diagnostic tools with a single indicator (Glas et al., 2003). It is the odds of positivity in subjects with a disease relative to the odds in subjects without disease and it is dependent on sensitivity and specificity (and is independent of prevalence) (Šimundić, 2009). However, there are some problems associated with utilising a single measure of association and therefore it should not be used in isolation (Pepe et al., 2004) with receiver operating characteristics (3.7.4) being offered as a suitable alternative by Böhning et al. (2010). Of note, it is not possible to distinguish between a test with high sensitivity and low specificity and a test with low sensitivity and high specificity, and can be difficult to interpret (Chang et al., 2012). Therefore, it is presented in this thesis solely as an additional indicator rather than for the main analysis of TUB tool accuracy.

3.7.4 Receiver operating characteristics

Receiver operating characteristics (ROC) is a way of combining sensitivity and specificity of a measurement tool against a dichotomous outcome (e.g. ISS>15). This is achieved by plotting sensitivity against one minus the specificity; if the area under the curve is 1 then the tool has optimal sensitivity and specificity. If the result is 0 it has neither sensitivity or specificity and if 0.5 then sensitivity equals specificity and there are therefore likely to be as many false positives as true positives. The minimum acceptable area under the curve is considered to be 0.7 (Drennan and Curtis, 2013).

The ROC curve can be used to calculate the cut-off value that delineates an ‘abnormal’ or positive result from a ‘normal’ or negative value (Peat et al., 2001).

Whilst this is not pertinent to the performance of the TUB tool as it is a dichotomous (‘triggered’ or ‘not triggered’) outcome, this test was used to evaluate other trauma triage tools against the study data.

3.7.5 Logistic regression

Logistic regression was carried out in SPSS and used to analyse the influence of each component of the TUB tool.

Regression analysis is described by Angelini (2019) as a useful statistical learning technique to infer the relationship between a dependent variable (also known as the response variable or outcome) and the variables (predictors, explanatory variables or covariates). Logistic regression, as opposed to linear regression, is selected when the outcome variable (in this study ISS <15 or ISS >15) is dichotomous (Bruce et al., 2018). An advantage of regression analysis is that it allows the evaluation of multiple explanatory variables (Hoffman, 2019).

This study developed a model based on the ten elements of the TUB tool (3 physiological and 7 anatomical). Multivariate regression is used to summarise the relationship between an outcome variable (ISS <15 or >15) and a number of explanatory variables (e.g. physiological variables such as blood pressure, heart rate, respiratory rate). Explanatory variables are entered to obtain odds ratios (ORs) that show the independent effect of each variable, adjusted for the other variables in the regression. The study design of this project does not include matching of cases and so this can be described as unconditional logistic regression (Bruce et al., 2018). As the response variable (ISS <15 or ISS > 15) is binary and there are multiple covariates, this study set up a binomial logistic regression (Jakaitiene, 2019) or binary logistic (Pallant, 2016). The independent variables may be either continuous (e.g. blood pressure) or categorical (e.g. presence of major pelvic fracture). Additional tests are utilised within statistical packages to evaluate the performance of the model (Bruce et al., 2018).

Pallant (2016) describes the importance of setting up the coding of responses to each of the variables carefully. Dichotomous should be 0 and 1 with 0 assigned to the absence of the characteristic of interest. For continuous independent variables, high values should indicate more of the characteristic of interest. Although the explanatory variables or predictors in the model can be continuous or categorical variables, logistic regression is best suited to measure the effects of exposures or

explanatory variables that are binary variables. Therefore, in this study, the responses to the physiological variables were coded as present or absent as follows:

Table 3-3 Categorical variables for physiological components of TUB tool

TUB Component	**Categorical variable**	**Coding**
Sustained respiratory rate <10 or >29	RR trigger	0 – no 1 - yes
Systolic blood pressure <90mmHg or absent radial pulses	SBP trigger	0 – no 1 - yes
GCS motor score of 4 or less	GCS trigger	0 – no 1 - yes

Where continuous variables are included, logistic regression will produce an estimate of risk for each unit of measurement. This means the assumption that the risk effect is linear over each unit of the variable must be met and the relationship should not be curved (Barton and Peat, 2014). Therefore, it is unsuited to physiological variables where a 'normal' range is present and numbers outside of that (higher or lower) indicate physiological abnormality which in this case is respiratory rate. Additional data was collected on heart rate which also falls into this case with a normal value being over 60 but less than 100 beats per minute.

Logistic regression models the log-odds of an event occurring (Muller and Maclehose, 2014), for example a major pelvic fracture. A key problem of regression modelling in small data sets is that the regression coefficients are overestimated for predictive purposes (Steyerberg et al., 2000). Whilst this data set is reasonably sized in totality, some of the variables (for example amputated limb) appear infrequently and so the number of cases analysed is small. This could affect the confidence with which the results for infrequently encountered injuries are interpreted. If input variables are highly correlated with one another (known as multicollinearity), then the estimated effect of each on the regression model becomes less precise (Ranganathan et al., 2017). This is likely to be the case with heart rate and blood pressure where hypovolaemia is initially compensated for by an increase in heart rate.

3.8 Comparison with other trauma triage tools

The review of the literature highlighted a number of trauma triage tools currently in use in ambulance services . Therefore, it was decided that a selection of these would be measured for their performance against this data set. The purpose was to assist in answering the second research question *'are there modifications that can be made to the WTUB tool in order to improve its accuracy?'*

The tools were chosen based on the following criteria:

- Previously evaluated in the literature
- Not designed specifically for use in mass casualty situations as this is a different type of triage
- Able to be applied in the pre-hospital field quickly and easily (either manually or electronically as most services now use electronic patient records)
- Use data fields already collected in this data set

This final criterion removed many of the scoring systems in use around the world. For example, the American College of Surgeons Field Trauma Triage Tool requires information around mechanism of injury which is not consistently or objectively collected in this dataset. NTS performed well in a recent systematic review (Gianola et al., 2021) but requires the use of oxygen saturations as a physiological variable and it was not reliably recorded in this data set (3.5.3.1). Others (AIS, TRISS, APACHE II) require complex calculations which are not practicable in the pre-hospital environment. Therefore, the Trauma Revised Triage Score (T-RTS) (Kondo et al., 2011) and the Glasgow coma scale, age, and arterial pressure (GAP) (Ahun et al., 2014) were selected.

3.8.1 GAP scoring system

The GCS, Age and Pressure (GAP) score was initially developed as a clinical score to predict survival in trauma patients, although it has also been validated for use as a triage tool (Hasler et al., 2014). It has been shown to perform well in other studies (Rahmani et al., 2016) with a sensitivity of 73% and specificity of 95.5% reported (Mahnaz et al., 2019). Its simplicity, ease of use and accuracy demonstrated in the literature makes it an attractive alternative tool.

Table 3-4 GAP score values

GCS	
3-15	3-15 points
Age	
<60	3 points
>60	0 point
Systolic blood pressure (mmHg)	
>120	6 points
60-120	4 points
<60	0 point

Values are summed to achieve a maximum possible score of 24.

- Low 19-24
- Medium 11-18
- High 3-10

The MGAP (mechanism of injury, GCS, age, pressure) score originated in France and, in addition to the GAP scoring parameters contains a simple mechanism of injury category, recorded by TARN and scores an additional 4 points for blunt injury (as opposed to penetrating) (Hasler et al., 2014). This tool was not utilised in this study as the additional category was only available for TARN eligible patients and so not for the entire data set.

The GAP score has been validated against TARN data (Hasler et al., 2014) although the outcome measure was mortality at 30 days rather than need for trauma centre intervention or injury severity score. This study also suggested alternative cut-off points and re-categorised as below:

- Low 22-24
- Medium 19-21
- High 3-18

3.8.2 Triage - Revised Trauma Score

The Triage Revised Trauma Score (T-RTS) should not be confused with the Revised Trauma Score (RTS) as the former may be used at the scene to assist with triage whilst the latter only has utility in research and quality assurance (Moore et al., 2006, Champion et al., 1989)

Table 3-5 T-RTS score values

GCS	**Score**
13-15	4
9-12	3
6-8	2
4-5	1
3	0
SBP	**Score**
>89	4
76-89	3
50-75	2
1-49	1
0	0
RR	**Score**
10-29	4
>29	3
6-9	2
1-5	1
0	0

Code parameters from 0-4 based on magnitude of the physiologic derangement are assigned. Scores are summed to produce a maximum score of 12. Scores of 11 or greater are advised to be transferred directly to a trauma centre.

The ‘Transform’ function was utilised in SPSS to score each variable based on the physiological parameters collected and a GAP and TRTS was assigned to each case.

3.8.3 Prediction models

Various methods may be utilised to test various new models. One means employed in a Swiss study (Rutschmann et al., 2006) was a bespoke computerised triage simulator. Clearly the funding, time and expertise required for this type of testing are outside the scope of this study, but it does demonstrate the resources utilised in the pursuit of triage accuracy.

3.8.3.1 Threshold adjustments

Simple modelling was performed by selecting adjustments to physiological parameters. Once the parameters were adjusted, for example changing ‘systolic BP <90mmHg’ to ‘systolic BP <100mmHg’ cases which were affected by this change were then re-classified as TUB +ve and the 2x2 tables altered to reflect this. The sensitivity and specificity was re-calculated and is displayed alongside the current TUB tool in Chapter 5.

Chapter 4 Study Setting

4.1 Introduction

This chapter describes the location in which the study took place, including the geography, demographics, socioeconomic landscape, and factors which may contribute to trauma such as road safety and crime. It then goes on to describe the health economy in the region and where the Wessex Trauma Network sits within this. The purpose of this chapter is to provide background and context within which the study results can be interpreted.

4.2 Study setting

The setting for this project is the University Hospital Southampton (UHS), Hampshire, England, the Major Trauma Centre (MTC) for the Wessex region as shown in Figure 4-1 and Figure 4-7.

Figure 4-1 Wessex clinical network https://www.hampshirethamesvalleyclinicalnetworks.nhs.uk

UHS is one of two MTCs in the South Central Ambulance Service (SCAS) area. Figure 4-2 shows the location of the SCAS region (shown in green), in relation to its neighbouring services. The Isle of Wight has its own ambulance service within the Isle of Wight NHS Trust, also within the Wessex region.

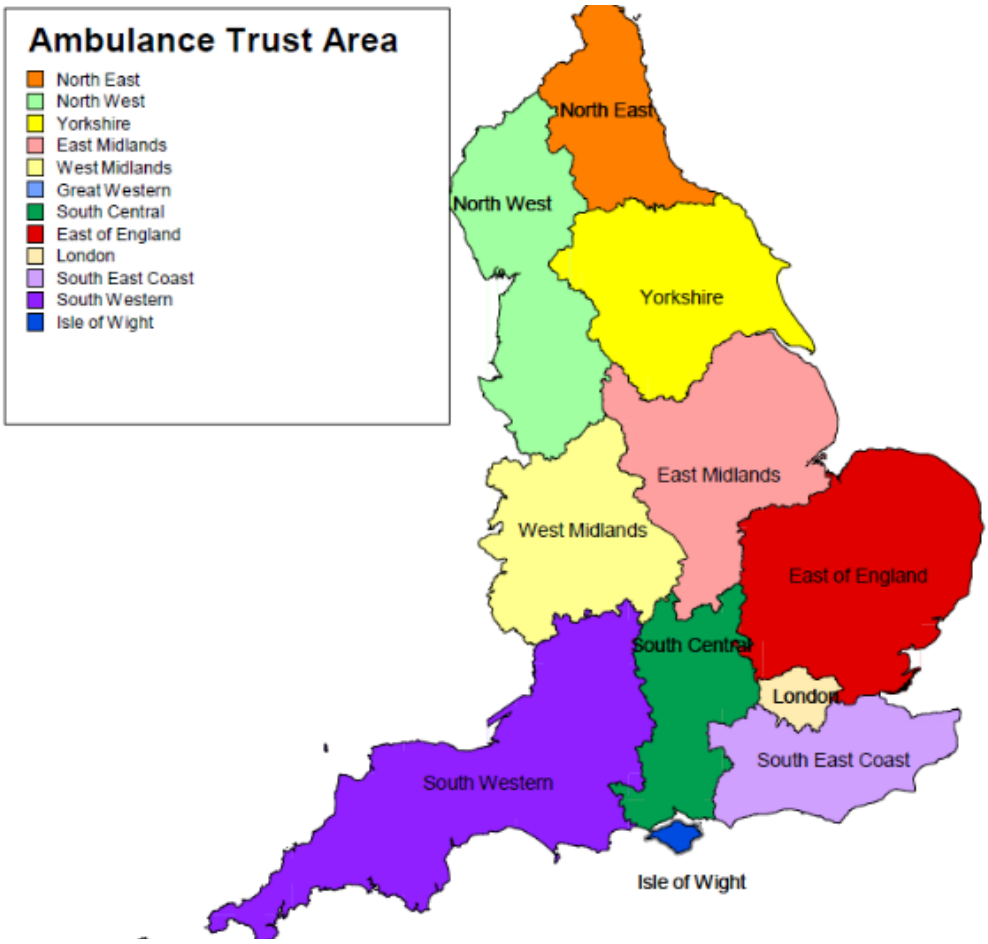


Figure 4-2 Ambulance Trusts and Foundation Trusts in England

https://neasappointments.com/about-us

4.2.1 Population

In 2018, the resident population of Southampton city was estimated by Hampshire County Council to be 256,459 with a male to female split of 50.9% to 49.1%, living in an estimated 106,237 dwellings (Southampton City Council, 2021a). Of this population, children between the ages of 0 to 4 years (pre-school) made up 6.2% which is similar to the national average. Approximately 19% of the population of Southampton were aged between 15 and 24 years, compared to 12% nationally. This is likely to reflect the presence of two universities in the city, attended by around 43,000 students. The over 65 age group accounts for 13% of the population, lower than the national average of 18.2%. The population of the city is predicted to increase by 4.7% by 2025, based on the Hampshire Small Area Population Forecasts. Data collected by NHS Digital records 289,684 people being registered with a General Practitioner (GP) in Southampton. The difference in this compared to population figures is likely to be attributable to people who live outside the city but are registered with a Southampton practice. Whilst there has been significant immigration to the area from Eastern Europe, the city does lack ethnic

diversity with 92.4% of residents being white (Public Health Southampton, 2017) compared to a national average of 79.1% (GOV.UK, 2020).

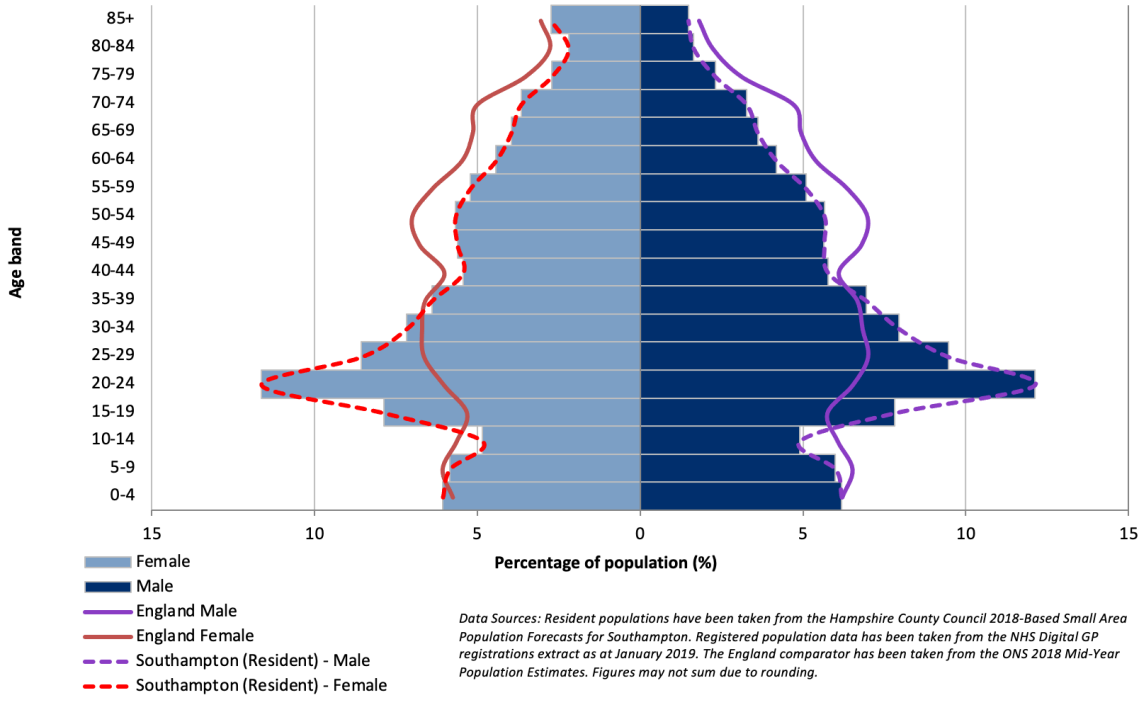


Figure 4-3 Population pyramid for Southampton Local Authority: 2018 (Southampton City Council, 2021a)

The population of the entire Hampshire Economic Area (Figure 4-3) was 1,867,500 in 2019 and all of these people would fall into the potential catchment area of the MTC in Southampton, as the next nearest are in Oxford, Bristol, Brighton and London. Whilst small growth in population size across all age groups are forecast to increase, the greatest increase (19.3%) is expected in the over 85 year-old age group (Hampshire County Council, 2019). However, these estimates were undertaken before the Covid-19 pandemic which is anticipated to have disproportionately affected this age group.

The population of Hampshire is split with 84.2% living in urban areas and 15.8% in rural locations (Figure 4-4).

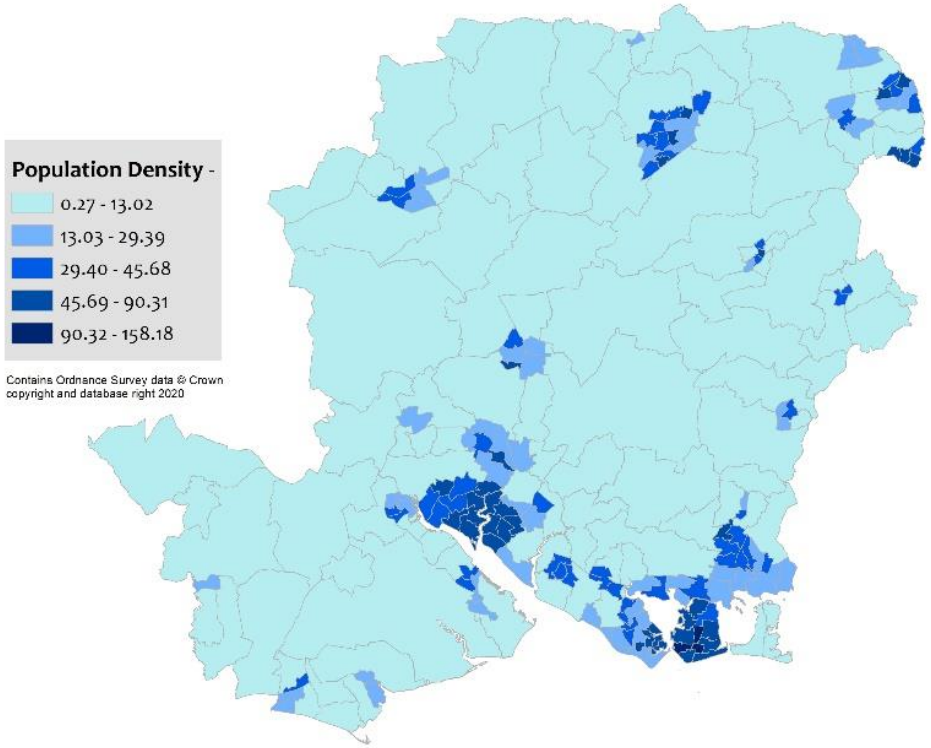


Figure 4-4 Population density (persons per hectare) 2019 (Hampshire County Council, 2019)

4.2.2 Life expectancy

Life expectancy in the Southampton area is lower than the national average for both men (78.3 years) and women (82.4 years) (Figure 4-5). Public Health England (PHE) produce an inequalities segment tool which demonstrates the contribution of several causes of death on the gap in life expectancy in an area compared to the national average. In this study setting, chronic lower respiratory diseases and heart disease are most significant in men and cancer (in particular lung cancer) and digestive diseases in women. There is also a discrepancy across the city with those in the most deprived areas living on average 6 years less than those in the least deprived areas. There is a higher prevalence of smoking in the more deprived areas which is likely to contribute to the impact of chronic lung disease and lung cancer on life expectancy.

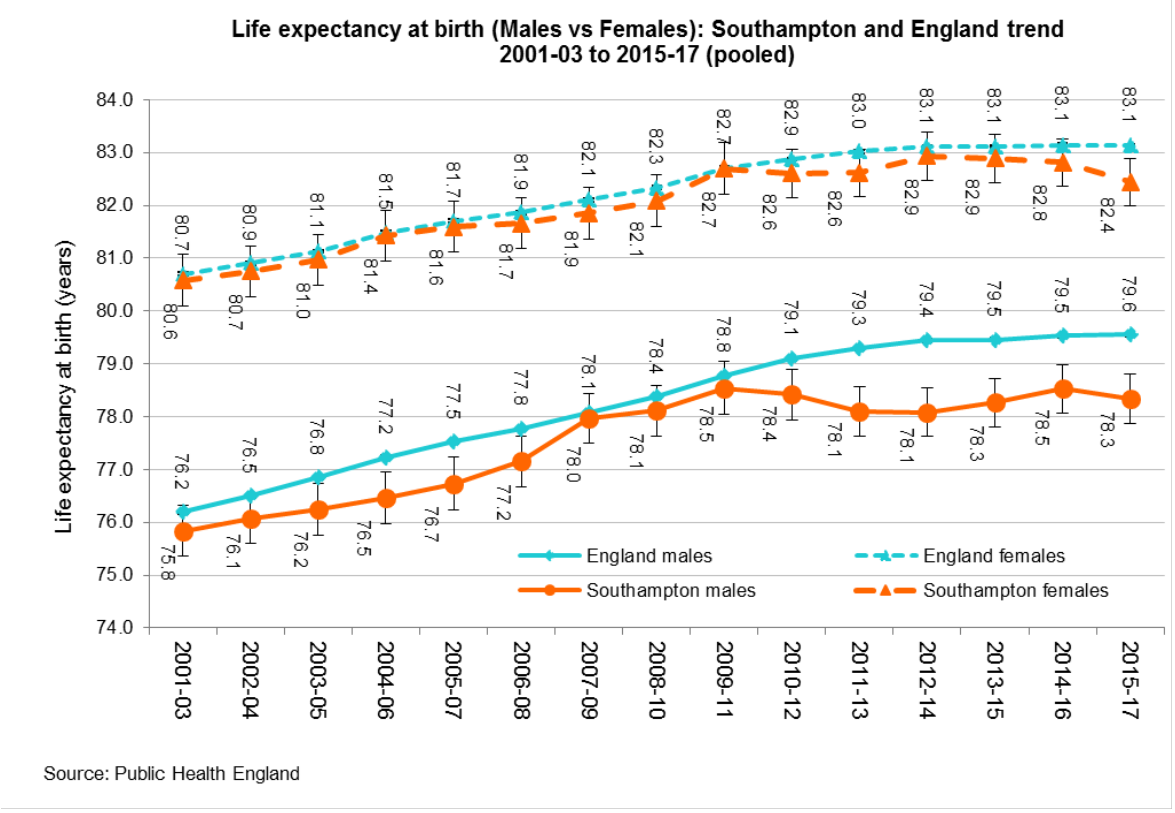


Figure 4-5 Life expectancy

4.2.3 Road Safety

Road traffic collisions are reported to the police via the STATS19 accident reporting form although there is no obligation to do this so some types of collision (e.g. pedestrian versus cyclist) are likely to be underreported (Department for Transport, 2021a). The reported road casualty rate per billion vehicle miles is calculated according to the total number of miles driven on a road network, to adjust for differences in the volume of traffic. In Hampshire this number is lower than in comparable local authorities but Southampton and the Isle of Wight have high road casualty rates (Figure 4-6).

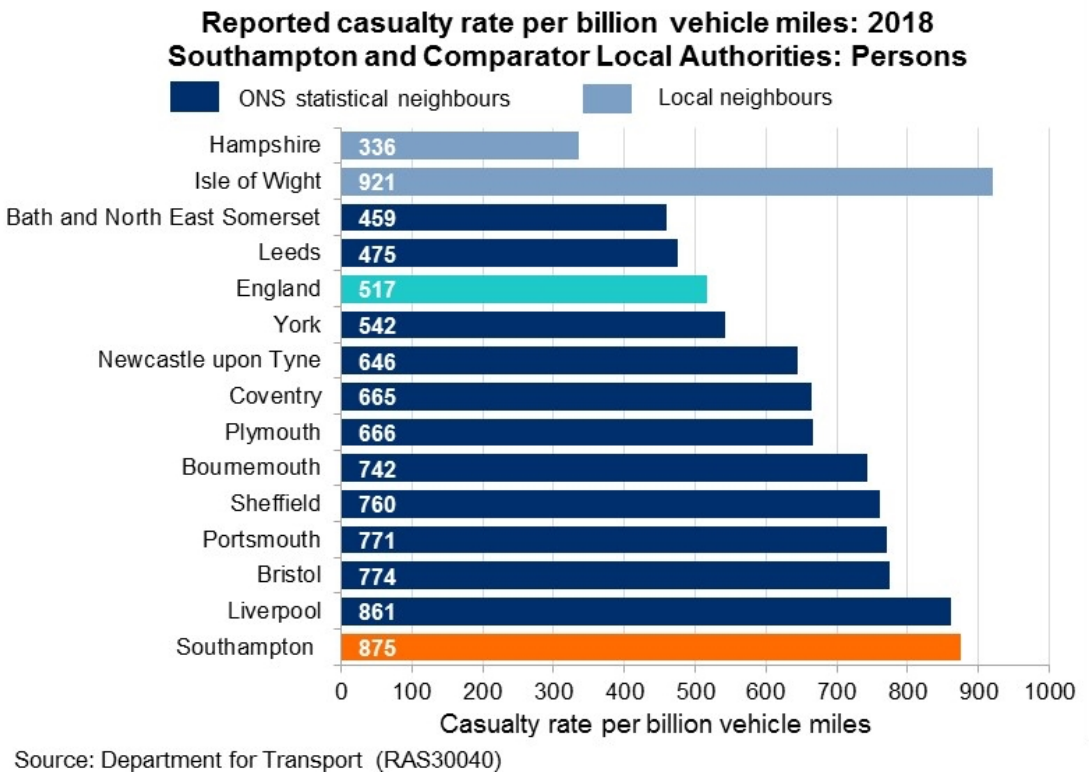


Figure 4-6 Road casualty rate

Almost 40% of all reported road casualties in 2016-18 (the period of this study) were aged between 16 and 30 years old. This data set also indicates that the fatal casualties from road traffic incidents for those aged under 25 years was 1.2 per 100,00 compared to 1.9 for the whole of England.

Table 4-1 Number of people killed or seriously injured. Data for 2017 (Department for Transport, 2021b)

Road user	**Southampton**	**Portsmouth**	**Rest of Hampshire**	**Isle of Wight**
Pedestrian	36	29	101	10
Pedal cycle	32	33	128	12
Motorcycle	20	33	191	29
Car (Includes taxis and minibus)	19	15	258	27
Bus or coach	4	0	2	3
Van / Goods vehicle	0	0	11	0
HGV	0	0	6	0
Other vehicle	1	1	10	1
TOTAL	**112**	**111**	**707**	**82**

4.2.4 Crime

The number of violent offences reported in Southampton rose from 9,544 in 2016/17 (the period of this study) to 10,300 the following year, an increase of 7.9%. In keeping with the national picture, there was a significant increase in serious knife crime over the same period (194 to 250 cases reported). Hate crimes rose by 25% and there was an increase of 7.3% in reported domestic violence incidents. Drug related deaths were 6.8 per 100,000 population compared to 4.3 recorded nationally (Southampton City Council, 2021b).

4.2.5 Deprivation

According to the Ministry of Housing, Communities and Local Government's (MHCLG) 2019 Indices of Deprivation (GOV.UK, 2019), of the 317 Local Authorities in England, Southampton is rated the 55th most deprived. This is a composite measure, based not only on incomes but access to housing and services, education and training and employment. 20.1% of children in Southampton are in low-income families, compared to the national average of 17%.

4.2.6 Tourism

Southampton is a major cruise ship port with several terminals in the city. There are a high number of domestic and international tourist trips made to the city with 2019 seeing in the region of 706,000 trips made (Kantar, 2020). The New Forest is also a popular tourist destination with 375,000 trips made in the same period with the Isle of Wight having a huge number of trips for its size (817,000) and therefore large variances in the population throughout the year and key holiday periods.

4.3 Health economy

4.3.1 Wessex region

HEE Wessex is a regional component of Health Education England (HEE), formerly known as a Deanery. It encompasses Dorset, Hampshire, the Isle of Wight, a southern portion of Wiltshire (which includes Salisbury) and the Channel Islands (Health Education England, 2021).

Wessex Trauma Network comprises all of the hospitals in the Wessex area along with the region's ambulance trusts (UHS, 2021b).

Wessex Trauma Network members:

- Basingstoke and North Hampshire NHS Foundation Trust
- Dorset County Hospital NHS Foundation Trust
- Isle of Wight NHS Trust
- Poole Hospital NHS Foundation Trust
- Portsmouth Hospitals University NHS Trust
- Salisbury NHS Foundation Trust
- South Central Ambulance Service NHS Foundation Trust
- South Western Ambulance Service NHS Foundation Trust
- The Royal Bournemouth and Christchurch Hospitals NHS Foundation Trust
- University Hospital Southampton NHS Foundation Trust

4.3.2 Wessex Trauma Network

The Wessex trauma network (Figure 4-7), served by the MTC University Hospital Southampton, covers an adult population of around 3.5 million and receives paediatric cases from neighbouring networks to the east and west. Each year, UHS receives around 50,000 emergency admissions with around 800 patients having major trauma (injury severity score > 15) (Eynon et al., 2019).

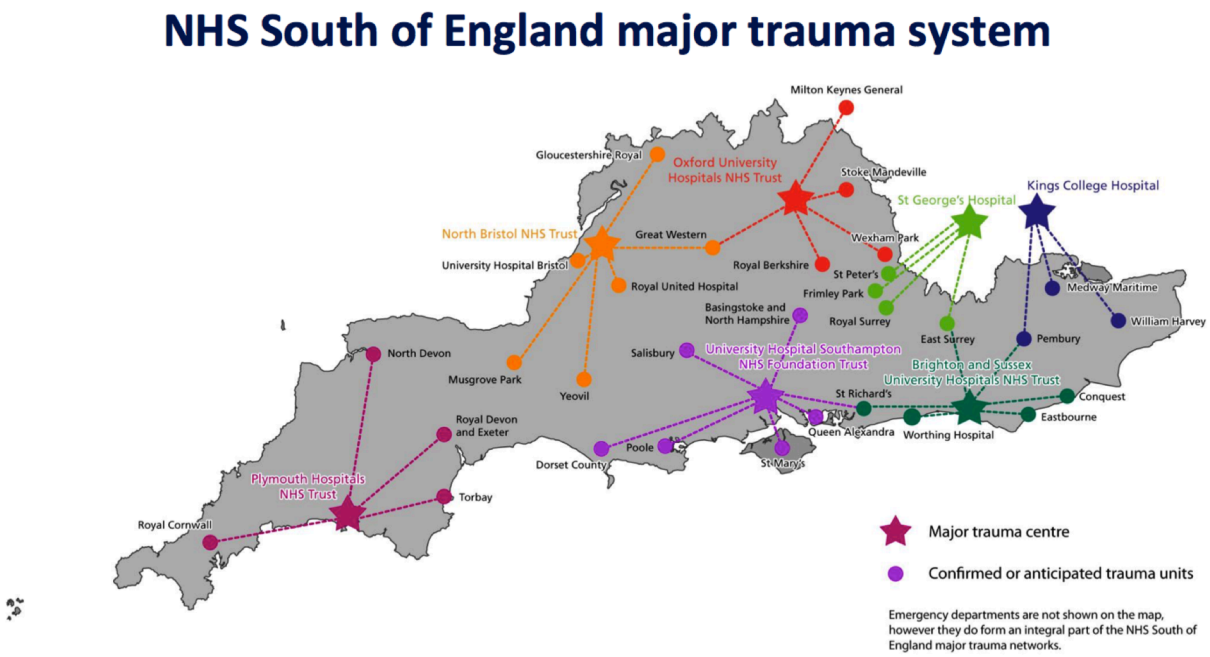


Figure 4-7 NHS South of England Major Trauma System

Figure 4-8 shows the 60 minute drive-time isochrone from UHS. The TUB tool stipulates that, if any of the anatomical or physiological findings are positive, the TU can be bypassed providing the MTC can be reached within 60 minutes and the airway and any catastrophic haemorrhage can be controlled. As can be seen, there is a great deal of overlap with other MTCs in the area and so some locations will be in the catchment area of 2 or even 3 MTCs. Aids such as the Major Trauma Triage App for smartphones can be used to assist crews if they are unsure which MTC is the closest to their location.

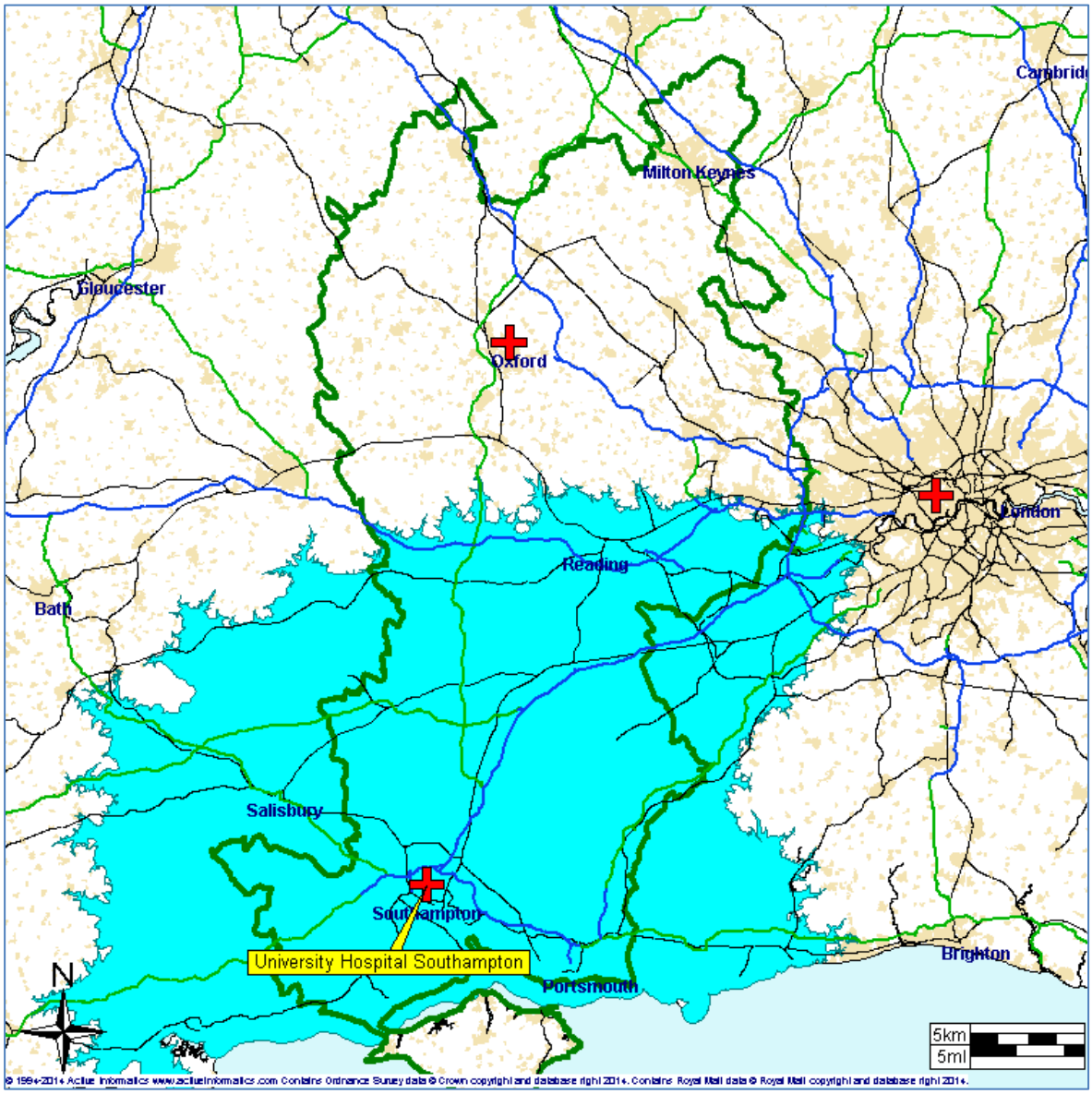


Figure 4-8 60-minute driving isochrone to UHS. MTCs shown as red cross and include St George's in London and the John Radcliffe in Oxford

4.3.3 University Hospital Southampton

UHS gained foundation trust status in 2011 and employs 11,500 staff. The Emergency Department at UHS deals with around 135,000 cases per year. It is a large teaching hospital with specialist services such as neurosciences, cardiac surgery and children's intensive care (UHS, 2021a).

The designation of University Hospital Southampton (UHS) as an MTC, combined with the addition of an on-site helipad, resulted in the hospital receiving patients from a greater geographical catchment area (Freshwater et al., 2014) with an associated impact on theatre time and intensive care days utilised by these

patients (Dickinson and Eynon, 2014). This study found that of the patients brought in by Helicopter Emergency Medical Services (HEMS) and admitted to ITU, the mean length of stay (LOS) on the unit was 7.9 days. Around a quarter of the patients in the study also required critical care outreach input during their admission. This was only a small study, carried out shortly after the implementation of the trauma network and did not consider other specialities such as vascular and neurosurgery. A newer and larger study in UHS revisited this area and found that total hospitalisation LOS for patients transported by HEMS was a median of 6 days and that 81.5% of patients transported by air had suffered trauma, rather than medical events and that ground transport by HEMS teams was more frequently used than at the time of trauma network inception (Wright et al., 2021).

As a Major Trauma Centre, UHS achieves 0.8 additional survivors per 100 patients (this is a figure calculated using logistic regression modelling and takes account of likely response to injuries and demographics which may affect outcome) (TARN, 2021a). This compares well to other surrounding MTCs in the south of England; Plymouth 0.4, Oxford 0.9 and Brighton 0.1. UHS is the regional Neurosurgical Centre, with 32% of patients with severe head injuries and 28% of those with spinal injury being transferred in having already been assessed in another hospital (TARN, 2021b).

4.4 Study population

This study contains data collected from patients brought by ambulance to University Hospital Southampton, following a traumatic injury, between 1st September 2016 and 31st August 2017. Patients brought in by private transport and those who first visited an alternative healthcare setting were excluded.

4.5 Summary

This chapter describes the study setting, in the context of the regional landscape and population, the local health economy and the regional trauma network. The setting was chosen as it is where the researcher works and is studying.

Whilst there are some differences in demographics compared to the national picture, for example the higher number of student-age population and the lack of ethnic diversity, it has commonalities with the UK in terms of an ageing population. Hampshire provides both urban and rural settings which will have comparability

with the wider UK, it has some characteristics which are less generalisable such as the presence of a coastline.

UHS has 100% compliance with the provision of data to TARN (TARN, 2021b) which highlights the robustness with which data from this source can provide.

Chapter 5 Results

This chapter presents the results of the data analysis. It aims to answer the research questions outlined in (1.5.2).

> *What is the accuracy of the Wessex Trauma Unit Bypass Tool in predicting patients with an Injury Severity Score of greater than 15?*
>
> *Are there modifications that can be made to the WTUB Tool in order to improve its accuracy?*

The chapter firstly describes the characteristics of the study sample and details of their arrival in the Emergency Department. These data are compared with a recent study (Moran et al., 2018) to place the findings in a national context.

The physiology of the trauma patients studied is described with reference to the presence or absence of major trauma. Using statistical methods, the accuracy of the TUB tool in predicting ISS>15 is outlined and those which were incorrectly triaged described. The relationship between triage category and age is explored, along with other characteristics of under and over-triaged patients.

The performance of other trauma scores against the same data set is outlined, and comparison made with the Wessex TUB tool. Finally, modelling of alterations to physiological thresholds and TUB tool components are explored. The results are summarised, prior to further discussion in Chapter 6.

5.1 Demographic characteristics of the study samples

5.1.2 Sex

In the adult patient group of 1035 cases, 59.5% (n=616) were male and 40.5% (n=419) were female. As previously discussed (4.2.1), the proportions of males in the general population of Southampton is around 51% to 49% and so males are over-represented in the trauma population when compared to the general population.

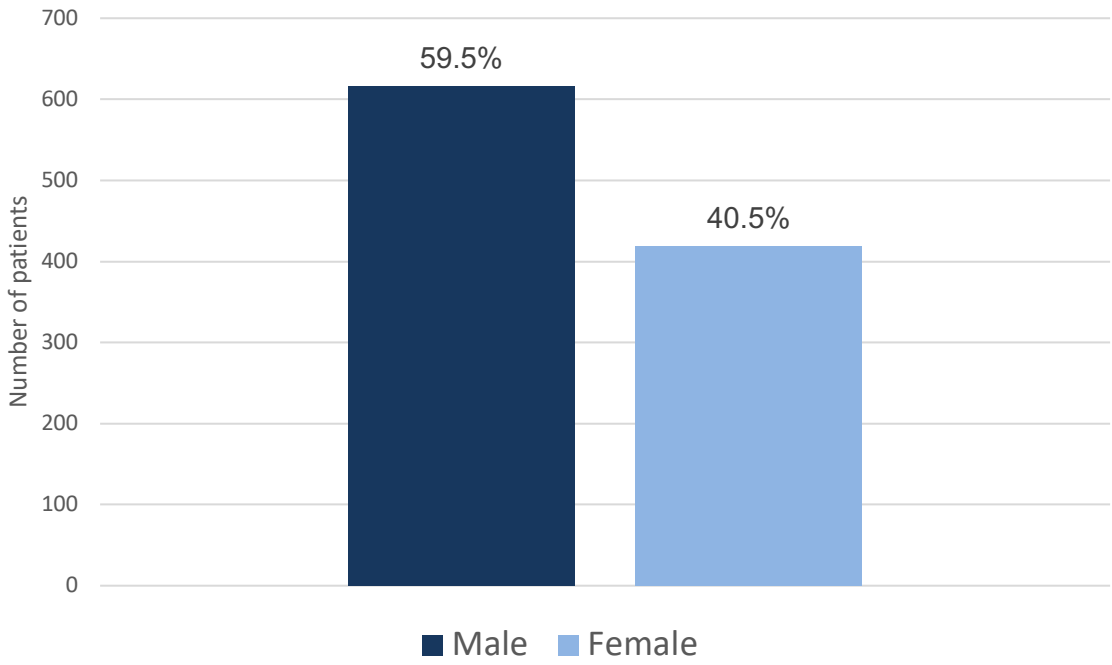


Figure 5-1 Patient numbers by sex

5.1.3 Age

The age range of the study sample is 16 to 106 years.

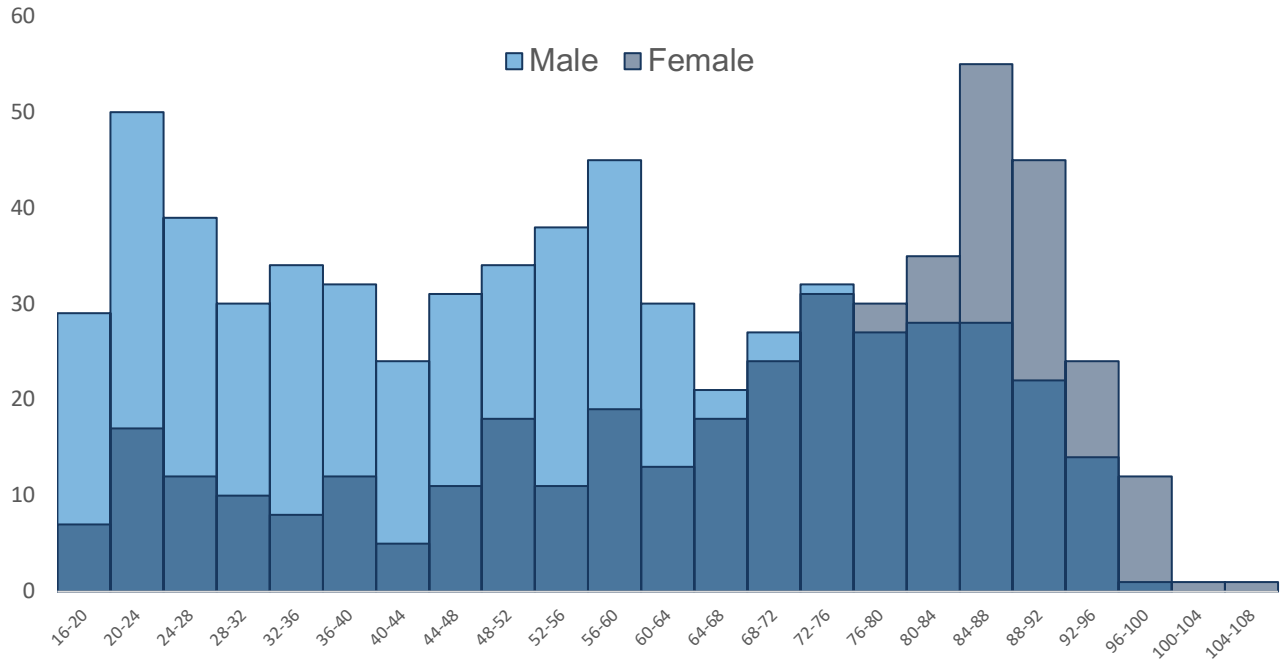


Figure 5-2 Distribution of age for all cases by sex

This histogram (Figure 5-2) illustrates the spread of cases with clear higher numbers of cases in the younger age group (early 20s) and in those over 80 years.

This differs quite markedly for the majority group in the study with male patients being predominantly younger than the overall mean. Conversely, female patients in the study were much older with a large rise in numbers after age 60 (Figure 5-2).

The mean age for all patients was 58.89 years. The male patient group were younger with a mean age of 52.37 years compared to 68.47 for the female patient group.

5.1.4 Time of patient arrival in the ED

Data collected included the date and time that patients arrived in the Emergency Department. There are some variations, for example the lowest number was in February as it is the month with the fewest days. Therefore, to mitigate for this, the average number of patients arriving per day was then calculated and presented for each month in (Figure 5-3). This shows that admissions for trauma tended to be lower in the winter months.

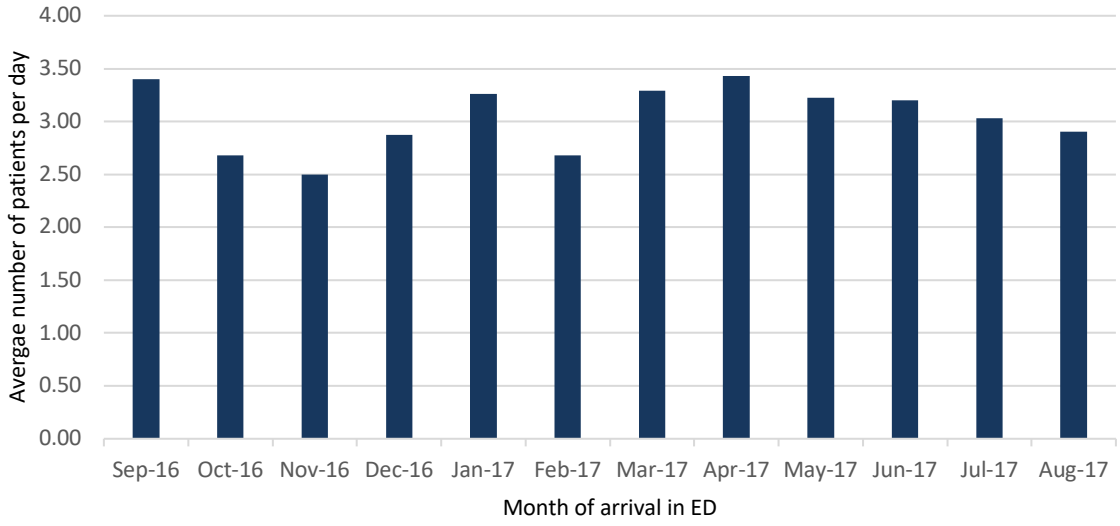


Figure 5-3 Patient arrivals by month - average per day

The time of day (by one-hour segments) that patients arrived is shown in Figure 5-4. As would be expected, the numbers decrease overnight between 0100 and 0800. It may seem surprising that the lowest number of patients arrived in ED between 0700 and 0800 which may be considered around the peak of commuter time. However, it should be noted that this is the time that the patient arrived in ED, not the time of the incident. Therefore, there is a period of time between the incident occurring, emergency services arriving, patient assessment, treatment and then transport to hospital. These details of time variance could be useful in

planning the provision of trauma services, in particular staffing numbers and access to e.g. theatres, CT scanners, etc.

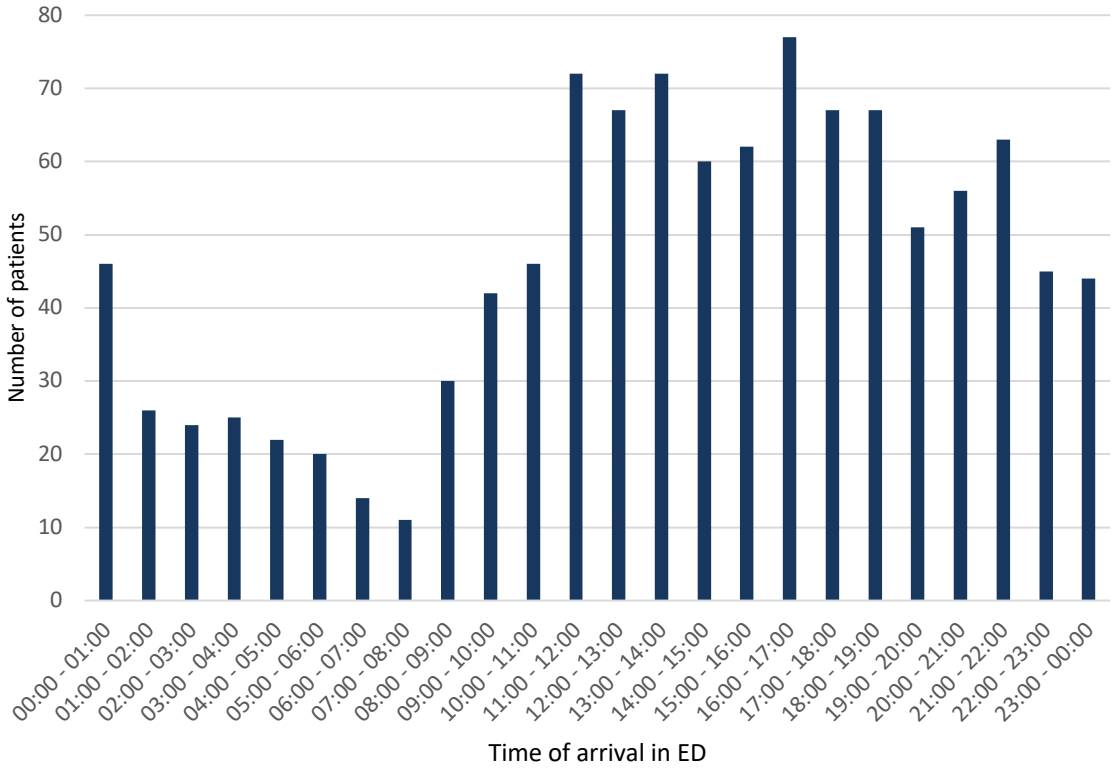


Figure 5-4 Patient arrival by time of day

5.1.5 Geographical location of incidents

Postcode data was not reliably available for all cases included in the study, particularly for those that were not TARN eligible, with only 234 (22.6%) having this information recorded. However, the postcodes that were available show a geographical spread of cases, from Weymouth, Dorset in the west to Bognor Regis, West Sussex in the east and Hermitage, Berkshire in the north to the Isle of Wight.

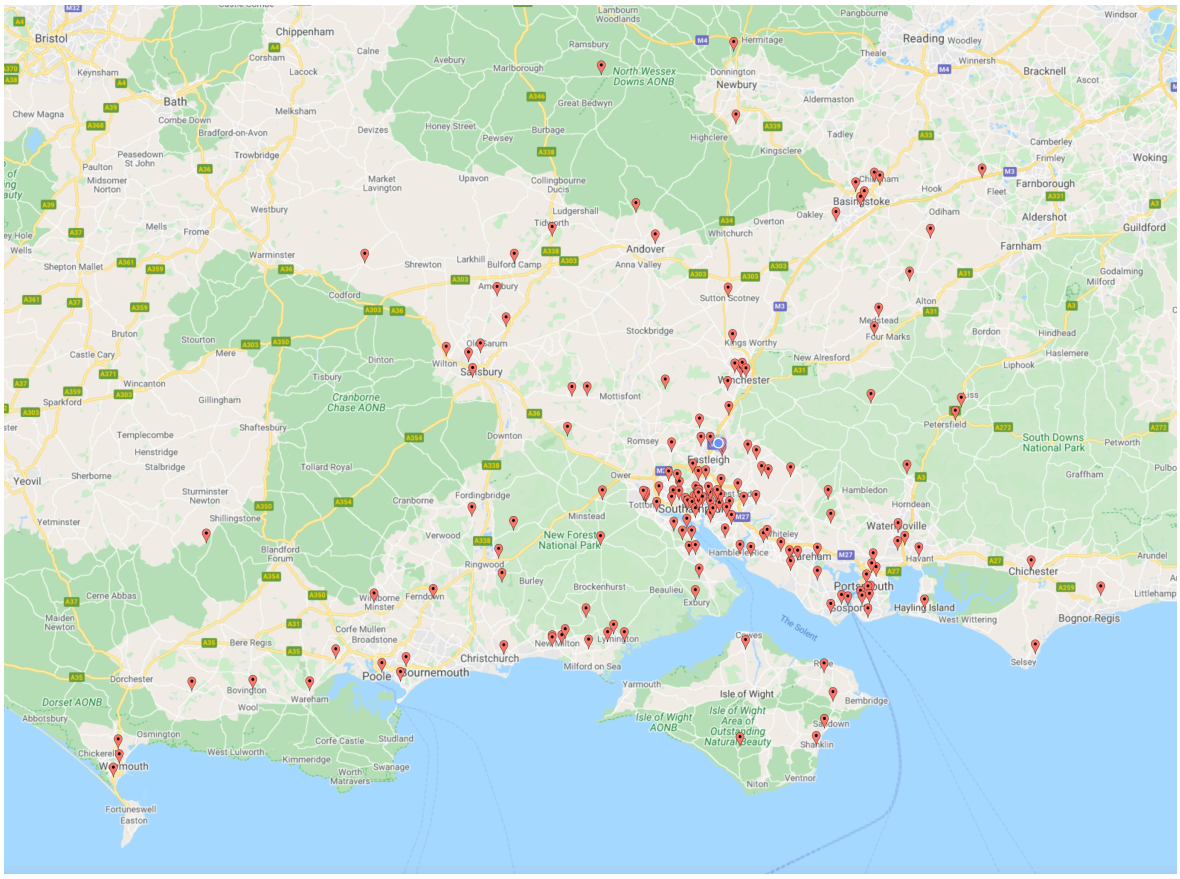


Figure 5-5 geographical spread of cases for which postcode was available

This largely reflects the geographical spread described by Freshwater et al. (2014) and Wright et al. (2021), which also used UHS as the study setting. However, these studies included secondary transfers and so some outlying locations (such as Jersey) were seen. As would be expected, the greatest number of patients were from the Southampton area as UHS is also the Trauma Unit for its own local area.

Access to a full set of location data could help to identify patients that had been brought to UHS in preference to a closer TU (i.e. had 'bypassed') although there are some difficulties in terms of distance by road, type of road (e.g. longer transport via motorway compared to shorter journey on narrow roads) or if 'as the crow flies' data should be considered in cases where a helicopter was used. Assumptions would have to be made by the researcher, particularly in cases where there was little difference in travel time between the TU and MTC.

The most accurate way to gain true bypass data would be to conduct a prospective study where pre-hospital clinicians are interviewed and to ask them if they bypassed a closer hospital. As previously discussed (3.2.1) this type of study has many attractive advantages but would need funding to undertake successfully.

5.1.6 Comparison of study sample with national results

A large and recent study by the National Clinical Director of Major Trauma and colleagues (Moran et al., 2018) reported on a longitudinal series of annual cross-sectional studies of care processes and outcomes over a period of 9 years. The data used was collected by TARN from 35 hospitals in England, with the main outcome being risk adjusted survival. Within this study, they presented demographic information and details around mechanism of injury which is presented in Table 5-1 for comparison with the Southampton data.

Table 5-1 Comparison of the study sample with England trauma populations 2016-17

	The study sample	**England trauma population (Moran et al, 2018)**
Number of cases	1035	248, 234
Median age (years)	60.0	59.6
Age > 64	44.9%	41.2%
Male	59.5%	61%
Mechanism of injury		
Assault	5.9%	7.4%
RTC	32.7%	26.3%
Low fall (<2m)	41.5%	47.2%
High fall (>2m)	16.5%	14.2%

The Southampton MTC population was proportionately older but largely similar in terms of characteristics of the sample. Road traffic incidents were higher in Hampshire than nationally and may reflect the presence of several major motorways and rural roads in this area, compared with urban areas where traffic may move more slowly. Falls accounted for the majority of trauma in both the local and national samples.

5.2 Physiological characteristics of patients

Table 5-2 provides information on the recorded physiological variables, both for the entire data set and also grouped separately by ISS category (< 15 and ISS >15). As previously discussed (5.1.2), over two-thirds of the major trauma group are

male, but the age range and mean ages are similar. The notable difference in physiology is the conscious level (GCS) of the major trauma group.

Table 5-2 Physiological characteristics of patients (median [min, max] values)

	ISS<15 (n=678)	**ISS>15 (n=357)**	**Overall (n=1035)**
Sex male female	375 (55.3%) 303 (44.7%)	241 (67.5%) 116 (32.5%)	616 (59.5%) 419 (40.5%)
Age (years)	60.7 [16, 106]	59.3 [17.6, 97.8]	60.0 [16, 106]
Systolic BP (mmHg)	138 [0,234]	136 [0, 250]	137 [0,250]
GCS	15 [3, 15]	14 [3, 15]	15 [3, 15]
O_2 saturations (%)	97 [0, 100]	97 [0, 100]	97 [0, 100]
Respiratory rate	18 [0, 90]	19 [0, 60]	18 [0, 90]
Heart rate	80 [0, 180]	84 [0, 170]	82 [0, 180]

On re-visiting the original data set, there were 12 patients who had a GCS of 3 but were not TARN eligible and so an ISS of 0 was recorded. This seems surprising but it is possible that these patients either had a medical cause for their unconsciousness, for example diabetic collapse, or that they were intoxicated with drugs or alcohol. There are challenges in managing these types of patients. For example, some patients suffer a medical event whilst driving, operating machinery or working at height for instance and can appear initially to have suffered major trauma. An open-minded approach must be adopted in the care of these patients to ensure that medical causes are considered and treated (e.g. thromboembolic events) but that traumatic injuries are not only considered but care is taken in patient handling to avoid their exacerbation. Imaging of these patients is crucial, particularly in understanding whether cardiovascular instability is related to blood loss and hypovolaemia or other pathophysiology. The second group, those under the influence of drugs or alcohol, can provide particular challenges in their assessment. In particular those who have fallen due to their impairment and present with signs of a head injury and reduced level of consciousness. It is not uncommon for some of these patients to be anaesthetised and undertake

computed tomography, only for there to be no injury found and the patient returns to their baseline once the effects of intoxication have worn off.

The respiratory rate across both groups is similar but the maximum recorded rate is high in both groups. It is possible that this is an error in recording, for example, heart rate has been entered in the respiratory rate box of a patient record. On returning to the original data set, there are 5 patients who have a respiratory rate of greater than 50 recorded. Of these, 3 were in the major trauma group and 2 in the ISS <15 group. One case has a respiratory rate of 90 recorded and oxygen saturations of 16 so it is likely that the values have been transposed.

5.3 TUB tool results and presence of major trauma

This section describes the accuracy of the TUB tool (3.7).

5.3.1 Test results

The number of patients that met one or more criterion of the TUB tool was 429 (41.4%). These cases were defined as having a 'positive' test, with the remaining 606 (58.6%) having a negative test.

5.3.2 Presence of major trauma

In total, 357 (34.5%) patients had an ISS of greater than 15 and therefore, as per the definition in use in this study, had suffered major trauma. The remaining 678 (65.5%) had sustained mild or moderate trauma or may have had no injuries found during their time in the hospital.

5.4 Accuracy of the TUB Tool

The accuracy of the Trauma Unit Bypass Tool is demonstrated by presenting the test results (TUB negative or TUB positive) in relation to the presence or absence of major trauma (ISS<15 or ISS>15) (Table 5-3).

Table 5-3 A 2x2 table of test result and presence of disease

	ISS >15	ISS <15	TOTAL
TUB +ve	183 (17.7%) True positive	246 (23.8%) False positive	429 (41.4%) TUB positive
TUB -ve	174 (16.8%) False negative	432 (41.7%) True negative	606 (58.6%) TUB negative
TOTAL	357 (34.5%) Major trauma present	678 (65.5%) Major trauma absent	1035 (100.0%)

This is a classic ‘two by two’ table which shows the test positive and negative against disease present or absent. It is used in calculations to test diagnostic accuracy (a summary of the terms described in 3.7.1 for calculating sensitivity and specificity is also included).

A total of 429 cases (41.4%) had a positive TUB tool, with 183 of these having an ISS>15 (true positive). The TUB tool was negative in 606 (58.6%) of cases, with 432 being true negatives with an ISS<15. The Pearson chi-square (21.62) (and continuity correction) both reach statistical significance (<0.001), demonstrating there is a relationship between ISS> 15 and TUB tool result.

The results presented in Table 5-4 are discussed in the following sections.

Table 5-4 Calculations on the accuracy of the TUB tool

Statistics	Value	Low 95% CI	High 95% CI
Sensitivity (Sn)	0.513	0.47	0.555
Specificity (Sp)	0.637	0.615	0.66
Positive Predictive Value (PPV)	0.427	0.391	0.462
Negative Predictive Value (NPV)	0.713	0.688	0.738
Positive Likelihood Ratio (+LR) = Sn / (1 - Sp)	1.413	1.219	1.63
Negative Likelihood Ratio (-LR) = (1 - Sn) / Sp	0.765	0.675	0.863
Diagnostic Odds Ratio = (Sn/(1-Sn))/((1-Sp)/Sp)	1.847	1.412	2.416

5.4.1 Sensitivity and Specificity of the Wessex TUB tool

Sensitivity of the Wessex TUB tool is 51.3% 95% CI (47%, 55.5%). This shows that the TUB tool performs virtually no better than chance in predicting the presence of major trauma with only just over half of cases of severe injury correctly identified.

The specificity is more accurate at 63.7% 95% CI (61.5%, 66%) but still unreliable in ruling out major trauma and need for transport to a specialist centre.

5.4.2 PPV and NPV

The positive predictive value of the TUB tool is 42.7% 95% CI (39.1%, 46.2%) and the negative predictive value is 71.3% 95% CI (68.8%, 73.8%). This demonstrates that if a patient is TUB negative, there is a reasonable chance that they have not suffered major trauma, but a positive test has no validity in practice in predicting ISS>15 (3.7.2).

5.4.3 Likelihood ratios

Likelihood ratios are used here to help understand diagnostic tests and incorporate both sensitivity and specificity (3.7.2). The positive likelihood ratio (LR+) for the TUB tool is 1.41 95% CI [1.22, 1.63] which describes how much the odds of

suffering major trauma increase when the TUB result is positive. The converse (negative likelihood ratio or LR-), i.e. the how much the odds of major trauma decrease with a negative TUB result, was 0.77 95% CI [0.68, 0.86]. This means that a positive TUB tool result makes the presence of major trauma 1.4 times more likely. Conversely, a negative TUB tool makes major trauma 0.77 times less likely than before the test was applied.

5.4.4 Diagnostic odds ratio

This test also utilises sensitivity and specificity but can also be computed in terms of positive and negative likelihood ratios. Diagnostic odds ratio (DOR) describes the odds of a positive test in those with disease relative to the odds of a positive test in those without the disease (3.7.3). It is of limited value in clinical practice but could be used to compare diagnostic test for the same disease. In this study, the DOR is 1.847, 95%CI [1.412, 2.416]. As described, in isolation this is of limited use but, were the tool to be evaluated again, comparisons could be made by using the same test.

5.5 Under and over triage

The number of patients classed as over-triaged (false positive) is 246 (23.8% of the entire sample) with 174 (16.8%) under-triaged (false negative). The remaining 615 patients (59.4% of the entire sample) were correctly triaged (either true positive (n=183) or true negative (n=432) as shown in Figure 5-6.

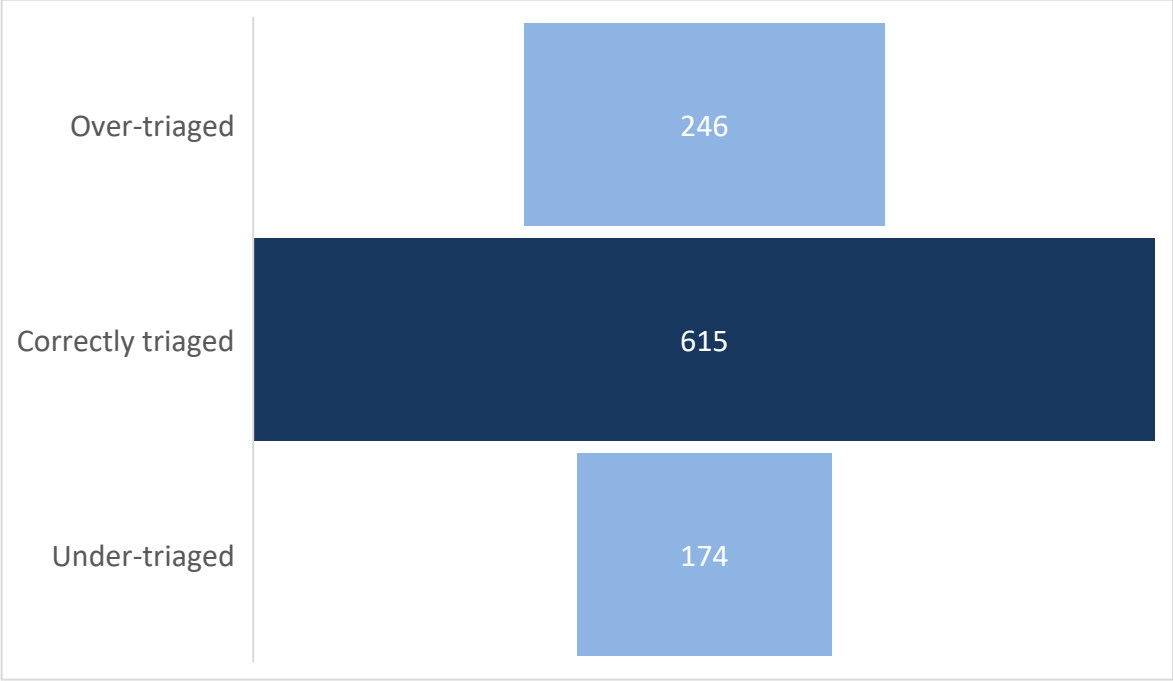


Figure 5-6 Proportion of patients in each triage category

When calculated as 1-sensitivity, the under-triage rate is 48.7% and when calculated as 1-specificity, the over-triage rate is 36.3%.

5.5.1 Relationship between age and triage category

The over-65 years of age group are more likely to be under-triaged than the younger cohort with the under-65s also more likely to be over-triaged (Figure 5-7 and Table 5-5).

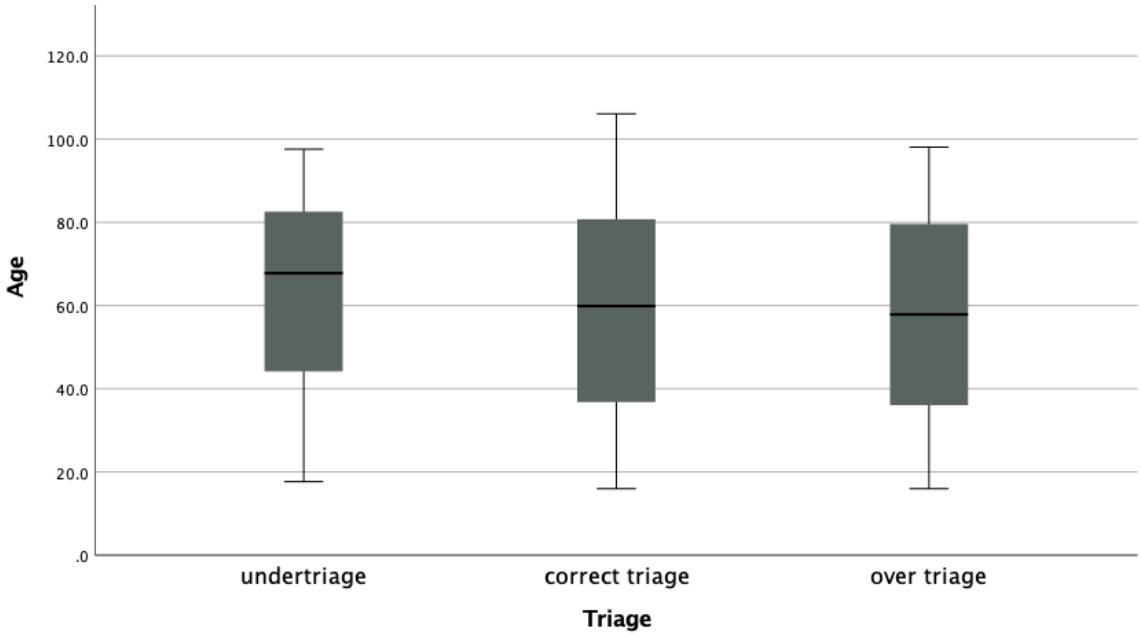


Figure 5-7 Boxplot of age by triage category

Table 5-5 Crosstabulation of age and triage category (number of cases and percentage of all cases)

		Triage category			
		Under triage	Correct triage	Over triage	TOTAL
Age category	65 years and under	83 (8.0%)	341 (32.9%)	146 (14.1%)	570 (55.0%)
	Over 65 years	91 (8.8%)	274 (26.5%)	100 (9.7%)	465 (44.9%)
	TOTAL	174 (16.8%)	615 (59.4%)	246 (23.8%)	1035 (100%)

Patients who are under-triaged have not had the extent or severity of their injuries appropriately recognised (2.7). This may be for a variety of reasons but, in this case, it could lead to patients being transported to a centre where the specialty services they may require are not available. Of note, this group of patients is older than the other groups.

Patients who are over-triaged may not suffer due to the level of care they require but there may be other factors which affect them such as being transported further away from home, family, and support systems. However, this is more likely to be of significance to patients who require additional care such as the elderly. Conversely it is the system rather than the individual that is affected in the case of over-triage in that resources may be directed towards these patients and then not available when a major trauma patient presents.

5.5.2 Relationship between physiological observations and injury patterns with triage group

As can be seen from Table 5-6, the under-triaged group had a higher level of consciousness than the other two groups and their mean systolic blood pressure was also higher. The latter finding may correlate with the older age of this group and the prevalence of chronic hypertension in older people. No patients who were under-triaged sustained limb injuries. This may be related to the visibility of these types of injuries when compared to those which are less likely to be seen externally, for example in the chest and abdomen. Patients who were over-triaged tended to have a higher instance of head, chest and pelvis injuries.

Table 5-6 Characteristics of patients by triage category

	Under triage	Correct triage	Over triage	All
Demographics				
Mean Age (years)	62.1	58.6	57.5	58.9
Male (%)	62.1	58.9	59.3	59.5
Physiology				
Mean GCS	14.4	13.3	13.8	13.6
Mean O2 sats (%)	95.1	92.5	92.4	92.9
Mean HR (bpm)	85.3	84	84.8	84.4
Mean RR (pm)	19.2	18.6	20.5	19.1
Mean SBP (mmHg)	141	136	133	136
Injury area (percentage)				
Head	32.2	30.1	41.5	33.1
Chest	16.7	24.7	30.5	24.7
Pelvis	0	7.5	43.1	14.7
Abdo	5.7	8.8	8.1	8.1
Limb	0	1.3	6.5	2.3
Spine	21.3	25	19.5	23.1

5.5.2.1 Characteristics of under-triaged patients

In order to be able to make improvements to the TUB tool, it is important to understand more about patients for whom it did not correctly identify major trauma when it was present. The results of logistic regression of the under-triaged group compared to those that were not under-triaged is shown below (Table 5-7).

Table 5-7 Odds ratio of physiological and anatomical variables of under-triaged patients

Variable	OR	95% CI	*p* Value
GCS	2.236	1.871-2.674	**<0.0001**
O2 sats	1.007	0.991-1.024	0.390
Heart rate	0.996	0.983-1.008	0.491
Resp rate	0.975	0.937-1.015	0.231
SBP	1.007	0.999-1.014	0.095
INJURY AREA			
Head	0.599	0.362-0.990	**0.046**
Chest	0.428	0.233-0.785	**0.006**
Pelvis	0.000	0.000-0.000	0.993
Abdomen	1.035	0.389-2.752	0.946
Long bones	0.000	0.000-0.000	0.997
Spine	0.924	0.535-1.598	0.778

This table demonstrates the Odds Ratio (OR) of anatomical and physiological variables in the under-triaged group. It shows that GCS and the absence of head or chest injuries reach statistical significance and are therefore meaningful.

An abnormal GCS is different to the TUB tool trigger which solely uses the Motor component of the scale. It is theoretically possible to have a GCS of 7 (when GCS<8 is commonly regarded as ‘unconscious’) and still not trigger the TUB tool. It is difficult to think of occasions when a patient could have a low GCS and not be considered to be at risk of major trauma, but the TUB tool does not identify these patients who may have suffered TBI but do not trigger the tool on GCS.

The absence of head and chest injuries in the under-triaged group suggests that, where these injuries exist, they are appropriately identified by the TUB tool in either ‘open pneumothorax or flail chest’ or ‘suspected open or depressed skull fracture’. This suggests that major injuries are identified by the TUB tool, but that perhaps more minor injuries or multiple injuries are less well identified. It is possible to obtain an ISS >15 with a collection of minor injuries rather than solely through life-threatening injury. Again, this raises questions about the outcome measure of ISS>15 rather than need for specialist input. However, certain patients, namely the

older group, can benefit from specialist ortho-geriatric input for multiple injuries in a way that may not be required for younger people (Aw and Sahota, 2014, Herron et al., 2017).

5.6 TUB tool criteria met

The following figure (Figure 5-8) demonstrates the frequency of each TUB tool criterion being met.

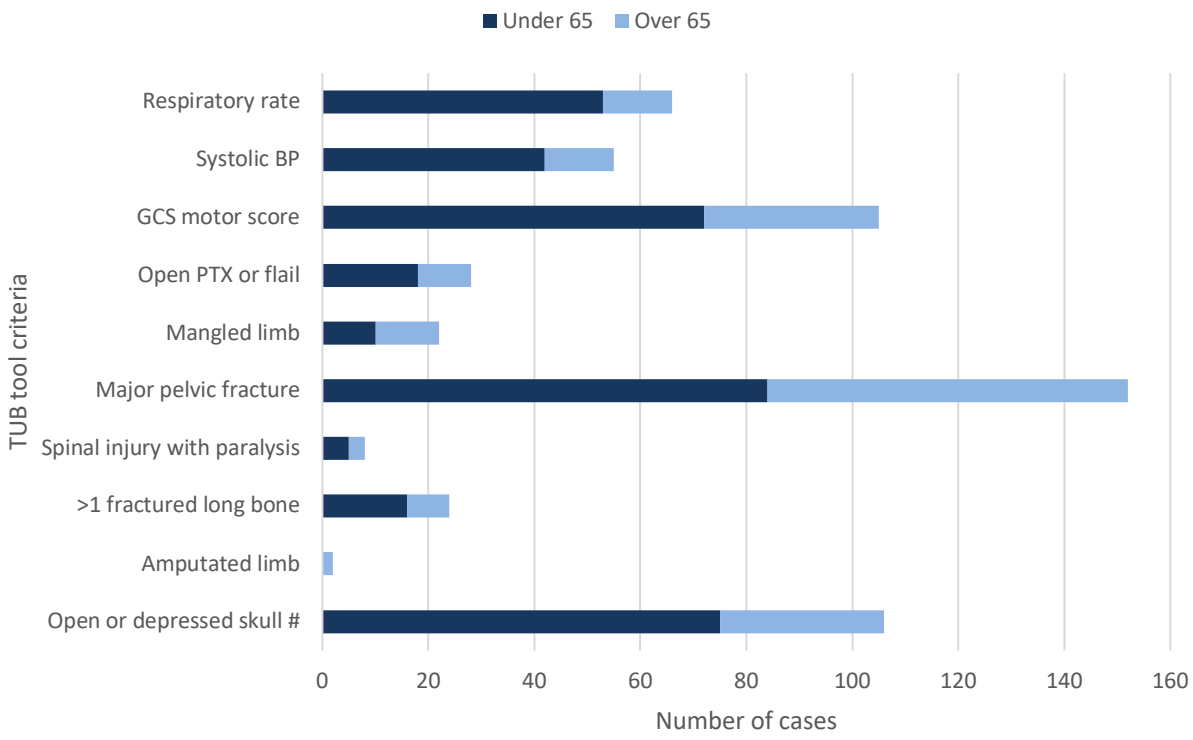


Figure 5-8 Frequency of TUB tool criteria being met

Of the physiological criteria, GCS motor score of 4 or less was the commonest 'trigger' for the TUB tool (105 cases) which could correlate with the high incidence of head injury (106 cases had an open or depressed skull fracture). Systolic blood pressure of less than 90mmHg accounted for 55 instances of the TUB being positive with respiratory rate being more commonly met (66 cases) although severe chest injury, as described by open pneumothorax or flail segment was less frequent (28 cases).

Major pelvic fracture was the most commonly identified anatomical criteria (met in 152 cases) but it is possible that there are some confounding factors here. The definition of what constitutes 'major' trauma in relation to the TUB tool is not clear (6.6). Some stable fractures which do not cause haemodynamic instability and do

not require emergency surgery may have been classified in this category as they appeared in the data as a pelvic fracture. Amputated limb (2 cases) and spinal injury with paralysis (8 cases) were the most rarely encountered injuries in this study.

Some cases met more than one criterion with the maximum being 4 criteria out of 10 being positive (Figure 5-9).

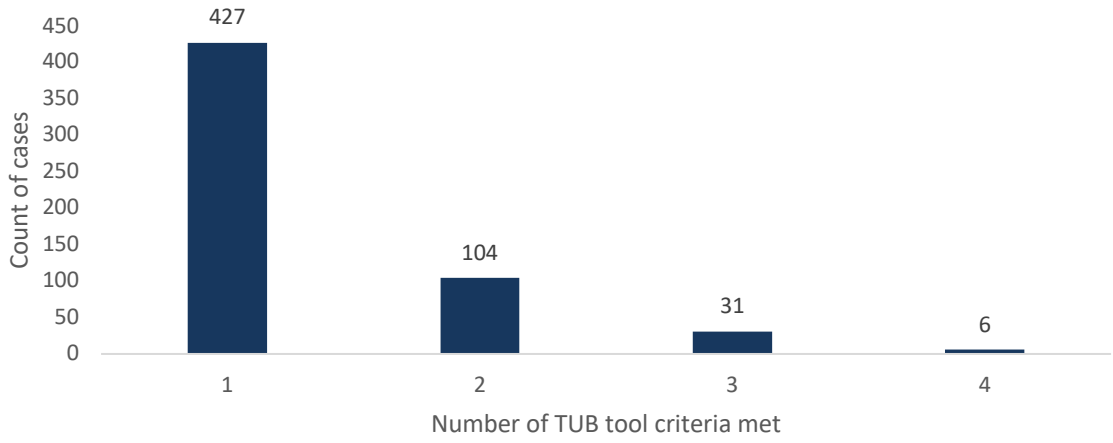


Figure 5-9 Number of TUB criteria met

5.6.1 TUB tool activation

The presence of a positive result against each component of the TUB tool is demonstrated in Table 5-8 along with the p-value associated with that element in predicting major trauma present or absent. It demonstrates that only the physiological variables reach statistical significance.

Table 5-8 Presence of TUB tool criteria by ISS group

TUB tool criteria	ISS<15 (n=678)	ISS>15 (n=357)	P-value
Respiratory rate <10 or >29	30 (4.4%)	36 (10.1%)	**<0.005**
Systolic BP <90mmHg	19 (2.8%)	36 (10.1%)	**<0.005**
GCS Motor score 4 or less	23 (3.4%)	82 (23.0%)	**<0.005**
Open pneumothorax or flail chest	17 (2.5%)	11 (3.1%)	0.734
Crushed, degloved or mangled limb	15 (2.2%)	7 (2.0%)	0.968
Major pelvic fracture	106 (15.6%)	46 (12.9%)	0.273
Neck or back injury with paralysis	5 (0.7%)	3 (0.8%)	1
>1 fractured proximal long bone	16 (2.4%)	8 (2.2%)	1
Amputated limb	1 (0.1%)	1 (0.3%)	1
Suspected open or depressed skull fracture	75 (11.1%)	31 (8.7%)	0.275

The small numbers in some of the groups (e.g. amputated limb) mean that no inference can be made. It is difficult to think of a situation where a limb was amputated but the patient had not suffered major trauma, however, one of the patients in this group had an ISS of 9 (moderate trauma but did not meet the threshold for major trauma).

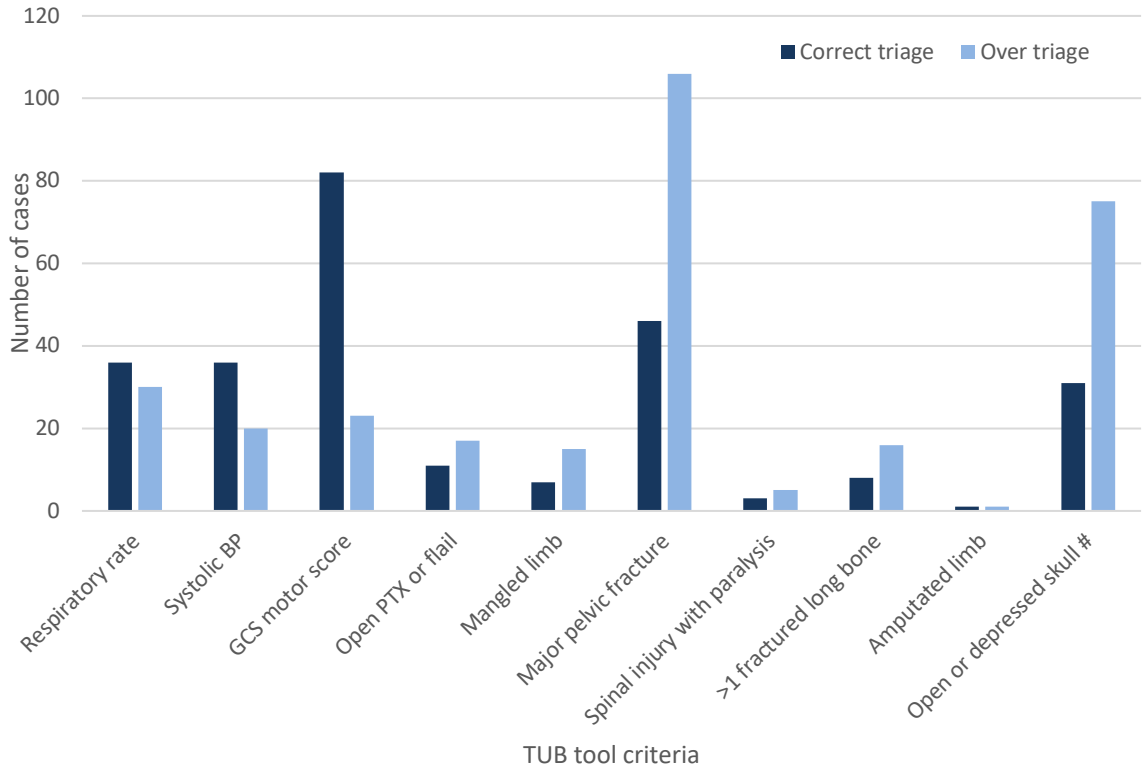


Figure 5-10 Incidence of TUB tool finding by triage group

The count of times each component is activated by correctly triaged or over-triaged sub-category is demonstrated in Figure 5-10. This bar chart demonstrates figuratively how well each component performs in terms of accurately triaging a patient. It is clear from this that the GCS motor score is a useful component of the TUB as it more frequently correctly identifies patients who have suffered major trauma than it over-triages. The converse is true for all of the physiological elements which frequently suggest major trauma present when the patient has an ISS of less than 15.

The physiological variables of the TUB tool, along with other physiological values collected in the data set are further explored in Table 5-9.

Table 5-9 Physiological values by age and presence of major trauma

	ISS<15		ISS>15		Overall	
Characteristics Median [Min, Max]	**<65 years**	**≥ 65 years**	**<65 years**	**≥ 65 years**	**<65 years**	**≥ 65 years**
Sex male	256 (69.9%)	119 (38.1%)	165 (80.9%)	76 (49.7%)	421 (73.9%)	195 (41.9%)
female	110 (30.1%)	193 (61.9%)	39 (19.1%)	77 (50.3%)	149 (26.1%)	270 (58.1%)
Age (years)	38.0 [16.0, 64.8]	82.6 [65.0, 106]	44.8 [17.6, 64.9]	81.6 [65.1, 97.8]	40.9 [16.0, 64.9]	82.3 [65.0, 106]
Systolic BP (mmHg)	130 [0, 221]	153 [71, 234]	125 [0,220]	150 [54, 250]	128 [0,221]	152 [54, 250]
GCS	15 [3,15]	15 [3,15]	14 [3,14]	14 [3,14]	15 [3,15]	15 [3,15]
O_2 saturations (%)	98 [0,100]	97 [0,100]	98 [0,100]	97 [0,100]	98 [0,100]	97 [0,100]
Respiratory rate	18 [0, 48]	18 [7, 90]	19 [0, 60]	18 [0, 36]	18 [0, 60]	18 [0, 90]
Heart rate	83 [0, 180]	79 [46, 169]	85 [0, 170]	83 [0,141]	84 [0, 180]	80 [0, 169]

This table shows the actual physiological values (rather than binary outcomes against the TUB tool categories). It highlights a number of interesting findings.

Firstly, the median systolic blood pressures are above normal range in all groups. Older major trauma patients had a higher blood pressure (150mmHg) than those in the under-65-year-old group (125mmHg). This is to be expected as older patients tend to have higher blood pressures and are more likely to suffer from hypertension, however, it does demonstrate the difficulty in using the same value to indicate low blood pressure (hypotension) across all ages.

Secondly, oxygen saturation levels also appear to be high in most groups. There is a possibility that this may be falsely inflated. In the critically injured patient, oxygen therapy is often one of the first interventions carried out in the emergency phase. This may mean that some readings were not obtained until after supplementary oxygen had been administered, giving a falsely high reading for the patient's clinical condition.

Finally, heart rate did not appear to alter substantially median values either. As previously described, this may be due to the fact that abnormal values can fall both below and above the normal range and so this method of analysis is not suited to categorising patients by blood pressure or heart rate.

5.7 Comparison with other trauma scoring systems

The performance of the TUB tool was compared to other scoring systems as described in an earlier chapter (3.8). The same data set was utilised so that a direct comparison could be made (Table 5-10). Both the GAP and the T-RTS overall had greater accuracy, but with much-reduced sensitivity. Specificity was high which would reduce over-triage and pressure on MTC resources, but they would also fail to identify the majority of patients with major trauma.

Table 5-10 Performance of TUB tool, GAP and T-RTS

	Sensitivity	Specificity	PPV	NPV	+ LR	- LR	Accuracy
TUB	51.26%	63.72%	0.43	0.71	1.41	0.77	59.42%
GAP	30.81%	92.92%	0.70	0.72	4.35	0.74	71.50%
T-RTS	38.00%	87.00%	0.61	0.73	2.92	1.53	74.11%

TUB – Trauma Unit Bypass tool, GAP, T-RTS – Triage Revised Trauma Score

PPV – Positive Predictive Value, NPV – Negative Predictive Value, + LR – Positive Likelihood Ration, - LR – Negative Likelihood Ratio

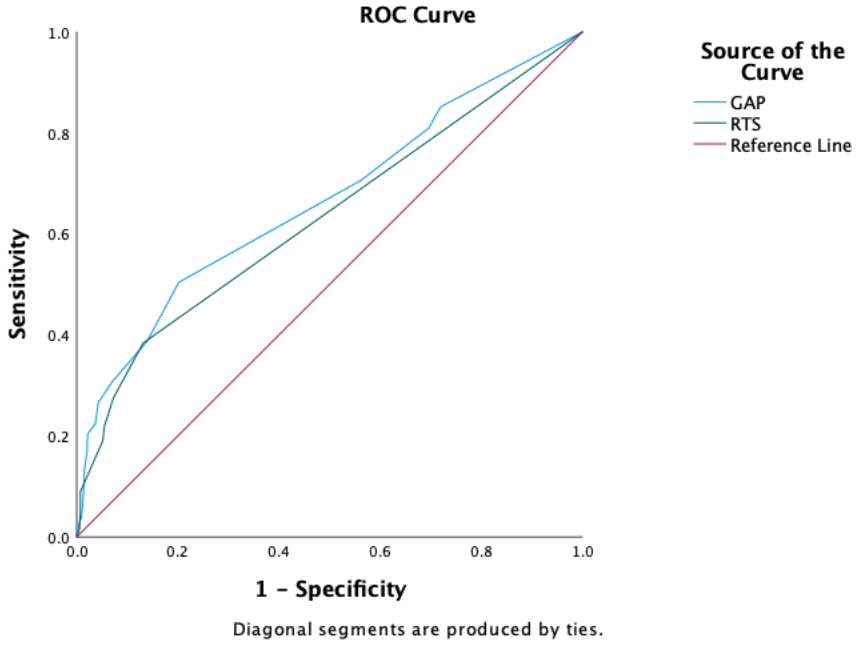


Figure 5-11 Area under the Receiver Operating Curve for GAP and T-RTS

Figure 5-11 shows that GAP achieved an Area Under the Curve (AOC) of 0.665 and T-RTS 0.632. If the AOC is 1 the tool is deemed to have perfect sensitivity and specificity. If the value is 0.5 the sensitivity and specificity are equal and 0 would

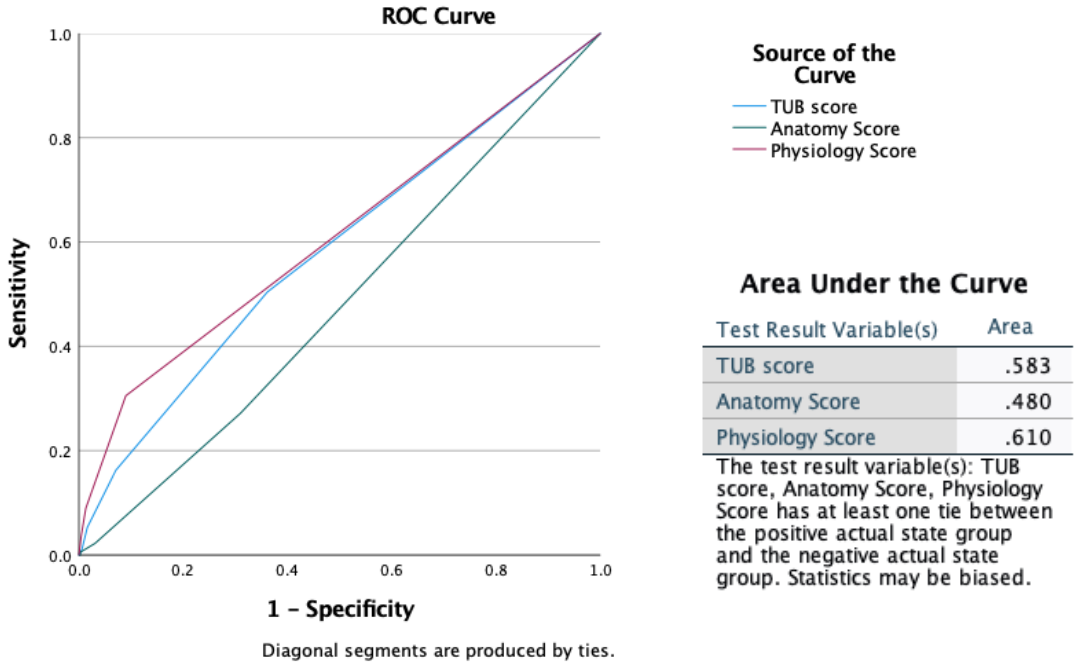
indicate that the tool has neither sensitivity or specificity. The minimum acceptable area under the curve is considered to be 0.7 (Drennan and Curtis, 2013). Neither GAP nor RTS achieve this against the data set used in this study. (The TUB cannot be compared alongside these systems as they utilise a total score which is linear rather than a binary 'positive' or 'negative' categorical value).

5.8 Modelling of modifications to the TUB tool

5.8.1 Creating a scoring system to predict major trauma

It could be hypothesised that, rather than utilising the TUB tool as a dichotomous output, i.e. positive or negative, that it be used to create a score. This would seem an attractive proposition as combination of injuries is likely to result in a higher ISS score.

To test this, the elements of the TUB were all given a value of 1 if they were activated and 0 if they were not met (as for above analysis). The elements were added up, firstly in the 'physiological' category and 'anatomical' category and then combined. This would provide a score from 0 for the TUB negative case up to a maximum of 10.



Area Under the Curve

Test Result Variable(s)	Area
TUB score	.583
Anatomy Score	.480
Physiology Score	.610

The test result variable(s): TUB score, Anatomy Score, Physiology Score has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.

Figure 5-12 Area under the Receiver Operating Curve for TUB tool composite

However, as can be seen from the ROC curve (Figure 3-1), a cumulative or combined score does not perform well either and so should be discounted as an alternative.

5.8.2 Logistic regression of TUB tool variables

Table 5-11 demonstrates each of the TUB tool variables and its effect on accurately predicting major trauma. Only GCS motor score of 4 or less reaches statistical significance ($p<0.001$). The odds ratio (OR) is 7.5 for this variable which means that, if it is present (GCS motor score of 4 or less), the chance of the patient having an ISS of greater than 15 is over 7 times more likely than if this component is not triggered (i.e. GCS motor score of 5 or 6). This of course is unsurprising given that a reduced level of consciousness would be associated by clinicians as being indicative of serious injury, particularly in the context of a head injury.

Table 5-11 Logistic regression for TUB tool variables (ISS>15)

Variable	Odds Ratio (OR)	CI	p
(Intercept)	0.43	0.37-0.51	**<0.001**
Respiratory rate <10 or >29	1.36	0.75 – 2.44	0.303
Systolic BP <90mmHg	1.68	0.87 – 3.25	0.123
GCS Motor score 4 or less	7.50	4.59 – 12.69	**<0.001**
Open pneumothorax or flail chest	1.58	0.69 – 3.46	0.259
Crushed, degloved or mangled limb	0.89	0.31 – 2.26	0.813
Major pelvic fracture	0.72	0.48 – 1.07	0.108
Neck or back injury with paralysis	1.20	0.24 – 5.04	0.803
>1 fractured proximal long bone	1.04	0.40 – 2.46	0.939
Amputated limb	2.71	0.10 – 72.44	0.495
Suspected open or depressed skull fracture	0.71	0.44 – 1.12	0.150
R^2 Tjur	0.104		

When each variable is described individually, including those not currently utilised in the TUB tool, none of them demonstrate an ability to predict major trauma.

Table 5-12 shows each physiological variable as either continuous (e.g. heart rate, respiratory rate) or ordinal (GCS). This is as opposed to Table 5-11 which uses nominal variables (simple yes/no). This comparison demonstrates that although the GCS component of the TUB tool (motor score 4 or less) is predictive of major trauma, the motor component in itself is not a predictor.

Table 5-12 Logistic regression for additional physiological variables (ISS>15)

Variable	Odds Ratio (OR)	CI	p
(Intercept)	1.97	0.45 – 8.84	0.359
Age	1.01	1.00 – 1.01	**0.032**
Sex	0.61	0.44 – 0.83	**0.002**
GCS	0.67	NA – 1.43	0.449
GCS Eye	1.35	0.58 – 15.98	0.592
GCS Verbal	0.81	0.36 – NA	0.706
GCS Motor	1.41	0.65 – NA	0.515
O_2 saturations	1.02	1.00 – 1.03	0.073
Heart rate	1.00	1.00 – 1.01	0.384
Respiratory rate	1.02	1.00 – 1.05	0.062
Systolic BP	1.00	0.99 – 1.00	0.143
R^2 Tjur	0.145		

In summary, these tests have identified that although the physiological components of the TUB tool are useful in predicting major trauma, each individual variable value (including those not currently used in the tool) are not.

5.8.3 Altering thresholds to improve the accuracy of the TUB tool

Various changes to physiological parameters may seem like a sensible approach to improving the accuracy of the TUB tool. Some current tools in usage utilise a composite GCS score (to include eye, verbal and motor score) rather than the motor score in isolation. Therefore, the GCS of less than 14 was selected as a new

'trigger' as it would not be activated by some confusion either from mild concussion or existing cognitive impairment (e.g. dementia).

The systolic blood pressure parameter was then also independently altered to less than 100mmHg and then <110mmHg to reflect the higher mean BP across all groups and to test if a higher marker of 'hypotension' was more useful.

The addition of heart rate as a physiological parameter was made, with the trigger set at 100bpm as this is what would constitute an abnormal value, often seen in physiologically shocked patients. However, heart rate can raise for other reasons including pain, fear and anxiety and may be affected by treatments such as splinting and provision of analgesia.

Finally, the threshold for altered respiratory rate was lowered to 25 per minute (although this is still physiologically abnormal) to evaluate if this would improve accuracy. As discussed later (6.5.1), it is however, often the least reliably measured as it generally has to be manually counted rather than obtained from a machine unlike heart rate and blood pressure measurements.

Table 5-13 shows the initial 2x2 table results (5.4) along with the sensitivity and specificity calculated in 5.4.1. It then goes on to show the same calculations performed on the data set when thresholds for the physiological variables are altered.

Table 5-13 Variations to TUB tool and effect on sensitivity and specificity

Current Tool

	ISS >15	**ISS <15**	**TOTAL**		
TUB +ve	183	246	429	Sensitivity	51.3%
TUB -ve	174	432	606	Specificity	63.7%
TOTAL	357	678	1035		

If change GCS to <14

	ISS >15	ISS <15	TOTAL		
TUB +ve	203	256	459	Sensitivity	56.9%
TUB -ve	154	422	576	Specificity	62.2%
TOTAL	357	678	1035		

If change SBP to <100mmHg (all patients)

	ISS >15	ISS <15	TOTAL		
TUB +ve	212	251	463	Sensitivity	59.4%
TUB -ve	145	427	572	Specificity	63.0%
TOTAL	357	678	1035		

If change SBP to <110mmHg (all patients)

	ISS >15	ISS <15	TOTAL		
TUB +ve	227	277	463	Sensitivity	63.6%
TUB -ve	130	401	572	Specificity	59.1%
TOTAL	357	678	1035		

If added HR>100bpm

	ISS >15	ISS <15	TOTAL		
TUB +ve	216	323	539	Sensitivity	60.5%
TUB -ve	141	355	496	Specificity	52.4%
TOTAL	357	678	1035		

If change RR to >25

	ISS >15	ISS <15	TOTAL		
TUB +ve	206	264	470	Sensitivity	57.7%

TUB -ve	151	414	565	Specificity	61.1%
TOTAL	357	678	1035		

All of these modifications resulted in an improvement to sensitivity but at the expense of specificity. The biggest improvement to sensitivity was made by changing the systolic BP to <110mmHg rather than 90mmHg as it is currently. This resulted in an increase from 51.3% to 63.6%. Sensitivity of over 60% (60.5%) could be achieved by adding in a new variable of 'heart rate >100bpm' although there was a drop in specificity from 63.7% to 52.4%.

5.8.4 Age specific alterations

Older people may present with a higher blood pressure than younger patients, even when they are hypovolaemic. In order to potentially address this, adjustments were made to the systolic blood pressure threshold on the physiological criteria, for patients aged 65 and over (Table 5-14).

Table 5-14 Effect on sensitivity and specificity of altering blood pressure thresholds in patients > 65

Current tool

	ISS >15	**ISS <15**	**TOTAL**		
TUB +ve	62	100	162	Sensitivity	40.5%
TUB -ve	91	212	303	Specificity	67.9%
TOTAL	153	312	465		

BP<100

	ISS >15	**ISS <15**	**TOTAL**		
TUB +ve	62	103	165	Sensitivity	40.5%
TUB -ve	91	209	300	Specificity	67.0%

TOTAL	153	312	465

BP<110

	ISS >15	**ISS <15**	**TOTAL**		
TUB +ve	67	113	180	Sensitivity	43.8%
TUB -ve	86	199	285	Specificity	63.8%
TOTAL	153	312	465		

BP<120

	ISS >15	**ISS <15**	**TOTAL**		
TUB +ve	69	130	199	Sensitivity	45.1%
TUB -ve	84	182	266	Specificity	58.3%
TOTAL	153	312	465		

Again, the sensitivity improved in each instance but at the expense of specificity. The accuracy of the tool would be affected (Figure 5-13) by such changes.

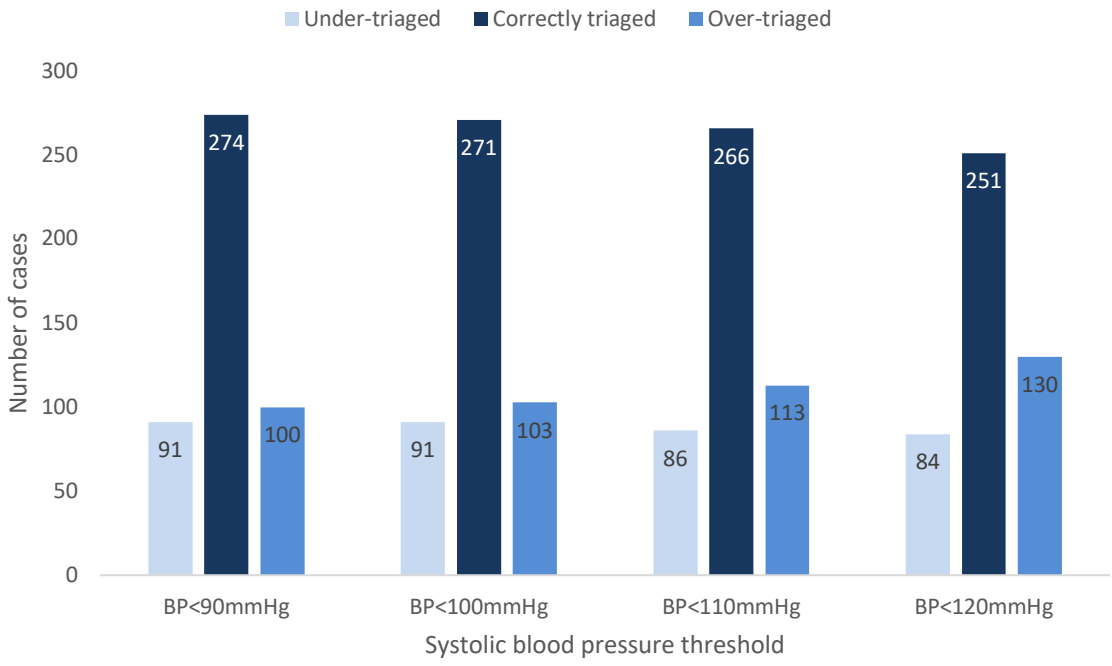


Figure 5-13 Changes to triage accuracy by adjusting systolic blood pressure parameter for patients over 65-years old

This graph demonstrates that increasing the blood pressure value would decrease the overall accuracy of the TUB tool although 7.6% (n=7) of under-triaged patients would be correctly triaged to an MTC if 'systolic BP<120mmHg' was used as a physiological parameter for this group of patients rather than the current 90mmHg. However, an additional 30 patients would be over-triaged to MTC care if this change were made.

5.9 Modifying the outcome measure

If ISS>9, in other words moderate, rather than severe trauma is used as an outcome measure, the results are as shown below (Figure 5-14).

	ISS ≥9	ISS <9	TOTAL
TUB +ve	304	125	429
TUB -ve	392	214	606
TOTAL	696	339	1035

Sensitivity	43.7%
Specificity	63.1%

Figure 5-14 Effect on sensitivity and specificity of altering definition of major trauma to ISS greater than or equal to 9

This shows that lowering the threshold to be considered 'major trauma' positive would decrease the accuracy of the tool in the same data set.

5.10 Summary of results

The study population is almost 60% male with a mean age of 58.9 years old. However, the male group is younger than the female group and the age range for all patients is 16 to 106. In terms of physiology between the major trauma and ISS less than 15 groups, the level of consciousness was lower in the more seriously injured. There is little difference in the other physiological measurements between the two groups.

Of the total sample of 1035 patients, 429 were TUB tool positive and 357 had an injury severity score of greater than 15. The sensitivity of the TUB tool is 51.3% with a specificity of 63.7%. The PPV is 42.7% and NPV 71.3%. The proportion of patients that were correctly triaged was 59.4%, with 16.8% under-triaged and 23.8% over-triaged.

The most commonly identified anatomical injury was pelvic fracture, followed by open or depressed skull fracture. The most frequent physiological trigger was GCS motor score of 4 or less. The most ‘triggers’ found in one patient was 4 with the majority only meeting one criteria of the TUB tool. None of the anatomical injuries accurately identified patients with an ISS greater than 15. Reduced GCS motor score was the most useful physiological finding.

Alternative trauma scores, when evaluated against the same data set, demonstrated an improved sensitivity but at the expense of specificity. Creating a composite scoring system from the TUB tool, rather than a binary ‘positive’ or ‘negative’ did not perform well in predicting major trauma.

Logistic regression analysis found that only the GCS trigger in the WTN tool was effective in predicting ISS over 15.

Modelling demonstrated that the sensitivity of the tool could be improved by altering physiological parameters or with the addition of heart rate (which is usually collected alongside other observations). However, this always comes at the expense of specificity, a trade-off which will be discussed further in the next chapter.

Chapter 6 Discussion

The main objective, as discussed in Chapter 1, of this study was to measure the accuracy of the Wessex Trauma Unit Bypass Tool in predicting an ISS of over 15 in patients who have been subjected to physical trauma. Further objectives were to analyse characteristics of patients who were incorrectly triaged, suggest modifications to the TUB tool and to test these against the original data set. The results of these analyses are presented in Chapter 5. This chapter will discuss the study findings, in the context of current major trauma practice in the UK, and also with reference to the international literature. Conclusions and recommendations for clinical practice are made and consideration of the limitations of this study and where future research could improve knowledge in this area discussed.

6.1 Performance of the Trauma Unit Bypass tool

6.1.1 Primary outcome: evaluating the sensitivity and specificity of the TUB tool

The primary outcome of this study was to evaluate the sensitivity and specificity of the Wessex Trauma Unit Bypass Tool, as described below and in section 5.4. In summary, the TUB tool does not perform well in predicting the presence of major trauma as defined by ISS>15.

6.1.1.1 Sensitivity

The sensitivity, or ability of the tool to identify major trauma, was 51.3%. This is in line with findings of Potter et al (2013) where the sensitivity of the Wessex TUB was 53%, although this was a much smaller study and only included patients who were TARN eligible and with an ISS greater than 15. These findings demonstrate that the Wessex TUB tool only correctly identifies just over half of the patients who have an ISS over 15. Therefore, if the tool was used in clinical practice as the sole means of deciding on transport destination, a high number of patients would be directed inappropriately. This could result in specialist services not being immediately available and the requirement for a secondary transfer to a major trauma centre.

Current NICE guidance (2016b) discusses the use of pre-hospital triage tools in major trauma, including the monitoring and audit of their use, but it does not set expectations in terms of the recommended sensitivity of the tool. This is in contrast

to the American College of Surgeons Committee on Trauma (ACS-COT) who set a benchmark of ≥95% sensitivity for field trauma triage tools (Newgard et al., 2013a). This recommended accuracy however, was not met by any of the tools considered by a recent systematic review (Gianola et al., 2021). The sensitivity of the Wessex tool is lower than all but one (Brown et al., 2011) of the tools discussed in the review of the literature (2.7).

To place the findings presented in this thesis in a real-world context, this result means that for every 10 patients who suffer major trauma, as defined by ISS>15, only 5 would be identified by the TUB tool. The other 5 could be inappropriately triaged to a hospital which may not meet their needs.

6.1.1.2 Specificity

The specificity of the Wessex TUB Tool in this study was 63.7%. The study by Potter at al. (2013) did not evaluate this for the Wessex TUB tool and so no comparison can be made, and no other study has so far evaluated this. Although the specificity is higher than the sensitivity, the tool still can be considered to perform badly in identifying patients who have not sustained major trauma. The rate of over-triage, calculated by 1-specificity, is therefore 36.3%, meaning over one-third of patients are incorrectly identified as requiring MTC care. As above, in order to appreciate this finding in clinical practice, this result demonstrates that for every 10 patients who are TUB positive, almost 4 have not in fact suffered major trauma. This means that a high proportion of patients could be transported greater distances and use the resources of a major trauma centre when they could safely be treated in a trauma unit.

Whilst specificity may have a less marked effect on patient care, it can affect systems which may become over-loaded when over-triage is high (6.2). Given that this is predominantly a systems issue, it is up to each network or health service to decide what a tolerable rate of over-triage is. This may be affected by other factors such as geography. For example, in areas of high population, greater levels may be acceptable as patients are not transported much greater distances to an MTC compared to a TU but in more rural areas this is likely to be more marked. A conference paper (Nepogodiev et al., 2012) in fact, described this in relation to the London Ambulance Service's trauma triage tool shortly after its implementation. They described an over-triage rate of 51% as being acceptable, in order to achieve an under-triage rate of only 6%.

The cost of over-triage should be considered, particularly in a social health care system where costs are not directly passed on to the patient. Newgard et al. (2013b) found the additional costs incurred by a patient being transported to a Level I trauma centre in the US ran to many thousands of dollars. If this were also the case in the UK, improving the specificity of the trauma triage tool to improve its over-triage rate may produce significant savings for the NHS.

6.1.1.3 Performance compared to other trauma triage tools

A number of trauma triage tools have been evaluated in the literature (Chapter 2). Since the literature review component of this study was initially undertaken, additional research has been published, including a large systematic review with meta-analysis by an Italian team (Gianola et al., 2021). The conclusion of this study was concordant with the findings presented in Chapter 2 in that the sensitivity and specificity varied across all available pre-hospital triage tools. They found that the Northern French Alps Trauma System (TRENAU) tool and NTS (New Trauma Score) are the most accurate tools for the adult population and were unable to draw a conclusion for paediatric patients where there was a large variability in performance. Of note, the Wessex TUB was assessed with reference to children, through the paper by Ardolino et al. (2015), but not for the adult trauma population.

The results from the review of the literature presented in this thesis are summarised in the figure below which shows the wide-ranging sensitivity and specificity of the tools evaluated.

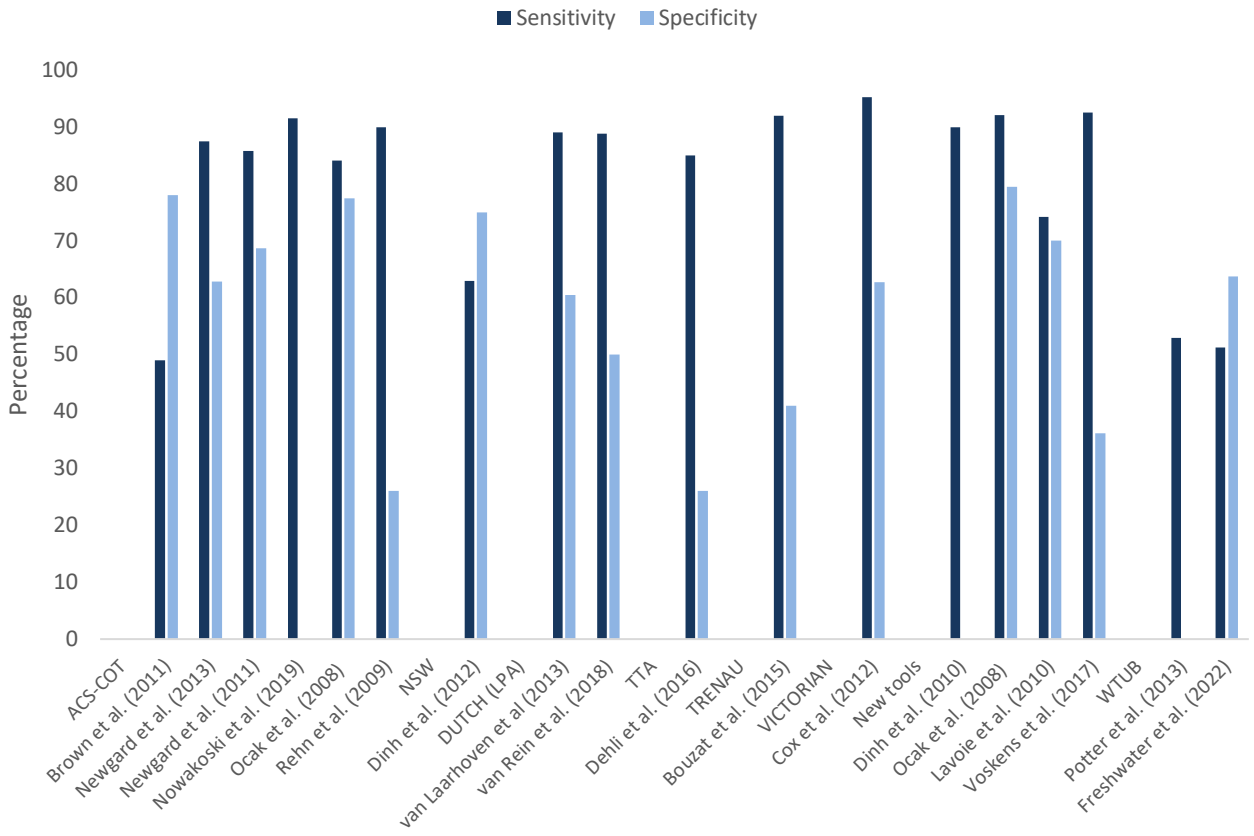


Figure 6-1 Sensitivity and specificity of trauma triage tools from the literature compared to Wessex TUB

One of the main issues when comparing various studies and triage tools is the range of methodologies employed, the data selected and the study population. As previously discussed (3.3) although ISS > 15 is commonly used to identify patients who should be triaged to a major trauma centre, other measures have been used, including need for surgery and specialist intervention.

Many studies are from outside the UK and so healthcare systems and trauma service provision may not be comparable. Of the UK studies, TARN data is frequently evaluated but this does not consider the portion of trauma patients who are not TARN eligible (Table 3-1) and so may exclude important subsets, and also lower acuity patients who may have been over-triaged. One of the strengths of the study described in this thesis is it includes not only patients who were retrospectively assessed as having suffered major trauma but also those who were assessed on initial presentation as requiring management in the resuscitation room of the ED.

6.2 Incorrectly triaged patients

Inaccurate triage affects both patients at an individual level, and systems, including impacting other patients by over-utilisation of resources. It is therefore important to study the characteristics of these groups of patients as described in 5.5. The consideration of under and over triage though must be evaluated in the context of the measure being used. This section considers the implications of incorrectly triaging patients and also argues that the sole outcome measure of ISS>15 is not the most useful in describing the need for transport to an MTC.

6.2.1 Over-triage

Over-triage, in the context of this study, describes the situation where a patient is incorrectly identified as requiring transport to a major trauma centre but is found on discharge to have an ISS of less than 15. The consequences of over-triage, (1.2.1) are that the MTC is overwhelmed by patients who do not require specialist services, and therefore do not have the available resources to look after a more severely injured patient that does need trauma team input. There can also be a financial cost implication (Newgard et al., 2013b) in over-triage with more expensive resource utilisation. This is particularly likely if the patient is pre-alerted as TUB positive, and a Level 1 trauma team assembled. There can also be an impact on other services, for example if a surgeon is called away from other work to attend the Emergency Department.

As shown in Figure 5-6, 246 (23.8%) out of 1035 patients were over-triaged, resulting in an over-triage rate of 36.28% when calculated as 1-specificity. This level of over-triage achieved though is likely to be at the expense of under-triage. This continues to be an issue with triage tools, in that the ideal situation is to achieve acceptable under and over-triage rates but that one usually impacts on the other (Newgard et al., 2013a).

Other metrics to ascertain over-triage rates have been suggested with Uleberg et al. (2007) suggesting that 1-PPV is deployed. If this were the case, the rate of over-triage of the Wessex TUB would increase to 57.34%. This means of describing over-triage is widely used in US trauma systems and is known as the Cribari formula or false discovery rate (Peng and Xiang, 2016).

The over-triaged group in this study were characterised by being younger than the under-triaged group with 40.7% being under 65 years old compared to 52.3% in the under-triaged group . Patients who were over-triaged also had a lower level of consciousness than the other patients which is discussed further in 6.5.3. It is not clear if this was due to a transient reduction in consciousness, for example due to intoxication, or if there is another reason for this finding. When the injured body parts are considered, the presence of a pelvic injury in 42.1% of patients incorrectly triaged as requiring an MTC is notable as no patients who were under-triaged had a pelvic injury. This may highlight one of the difficulties in the pre-hospital environment – accurately identifying injuries prior to imaging. It is possible that any pelvic pain could be triaged as a pelvic fracture but it may be a more minor fracture or soft tissue injury. As discussed later (6.6) the combination of suspected pelvic fracture and haemodynamic instability may be able to improve the accuracy of this component. It is also possible that the limitations of the study methodology as discussed in 3.5.3.2 in accurately identifying suspected major pelvic fracture may have influenced these results. Chest injuries were also more prevalent in the over-triaged cohort, possibly again due to the difficulty for pre-hospital clinicians in identifying injuries. The combination of suspected injury and physiological abnormality, such as increased respiratory rate or reduced oxygen saturations, should be explored in further research.

Whilst the impact of the level of over-triage shown may not be significant to the MTC, it is likely to disproportionately affect the ambulance services. In large urban areas such as London, the difference in travel time between attending a TU compared to an MTC may be small (Sinha et al., 2016). However, the travel distance variation in a more rural area such as Wessex could be significant. For example, if a patient was injured in Salisbury city centre, they would be 1.7 miles from Salisbury District Hospital with a drive time of approximately 6 minutes. If the patient was triaged to the MTC in Southampton, this would entail a drive of 21.6 miles, taking around 40 minutes. Not only would this increase the time to get to the hospital, the SWASFT ambulance crew would now be ‘out of area’ as they would be in the SCAS region. The time to return would make them out of service for longer, particularly if they had to return to an ambulance station to replenish equipment as is common following a high acuity incident. Any discussion around over-triage at a Network level would have to include consideration of the impact on ambulance service resources.

As discussed, the outcome measure of ISS>15 is significant when considering what is over-triage. Rates may be different if an alternative outcome was used. For example, a study by Harrell et al. (2020) compared the use of ISS>15 (an anatomical score) with a modified Need for Trauma Intervention (NFTI) criteria (Table 6-1). Rates of over-triage in their sample reduced from 55% with ISS>15 to 26% when using the alternative measure. This again highlights the need to consider whether a patient will benefit from MTC input rather than simply using an injury score.

Table 6-1 Need for Trauma Intervention (NFTI) criteria (Roden-Foreman et al., 2017)

Administration of packed red blood cells within 4 hours
Disposition from the ED to an operating room or interventional radiology within 2 hours
Admission to ITU
Death within 48hours

Their recommendation to adopt this approach is supported by their findings that patients who were mNFTI positive had longer length of stay, longer critical care LOS and significantly higher mortality than those who did not meet these criteria. The mean ISS for the patients that required specialist services was 8.18 which demonstrates the weakness of using ISS>15.

6.2.2 Under-triage

In this study, 174 patients (16.8% of the study sample) had an ISS>15 but did not trigger the TUB tool; this means they were under-triaged. When calculated as 1-sensitivity, the under-triage rate is 48.74% (5.4.5) This is in comparison to the ACS-COT recommendation of <5% (ACS, 2014). Therefore, the performance of the TUB tool falls well short. An alternative formula for calculating under-triage has been proposed Peng and Xiang (2016) which is under-triaged patients as a proportion of all major trauma patients. In this study that would be 174/429 = 40.56% which again is still outside of accepted levels.

As previously discussed, under-triage is associated with mortality where patients are not transferred to a trauma centre (Haas et al., 2010). Some patients who do not appear severely injured in the pre-hospital phase, can still go on to have mortality and morbidity. Benjamin et al. (2018) studied over 1 million patients who

were physiologically stable and did not meet trauma team activation criteria, and found a mortality of 1.1% which increased to 2.6% in patients over 60 years old, and when this group was further refined to include those with a history of stroke or congestive heart failure, the rate was 5.4%. Their recommendation was that patients with these co-morbidities be considered for transfer to a higher-level trauma centre. Increasingly, geriatricians are involved in the care of major trauma patients, and this may continue to be an area of expansion for specialist trauma services. Consideration of co-morbid conditions could also form part of a new tool for evaluation in future research.

A study investigating specifically older (over-65) patients who were under-triaged following motor vehicle collisions (Scheetz, 2012) found that the most common injuries associated with under-triage were TBI, spinal fractures and lower extremity fractures. This correlates with the findings described in this thesis. As discussed in 6.3.1.2 the under-triage of older patients is of concern (Alshibani et al., 2021, Hoyle et al., 2020).

Horst et al. (2018) used data from their established trauma network in Pennsylvania to attempt to analyse under-triage. They used composite outcome measures including ISS ≥9. As can be seen in the this doctoral study (5.9) altering the threshold of ISS from >15 to ≥9 results in substantial reduction in sensitivity of trauma triage (51.26% to 43.68%). However, in the Pennsylvania study, the under-triage rate was 32.2% for ISS≥9 and 33.6% for ISS >15. As they used transport to a trauma centre as the intervention, rather than use of a triage tool, this may provide some insight into reasons for under-triage. It is possible that patients with any but the most minor traumatic injuries are managed similarly as a group and that the reasons for non-transport to a trauma centre include additional factors. This could include proximity to hospitals as discussed below, familiarity with trauma networks and confidence in managing injured patients. In the US, there is an additional factor in that some hospitals incentivise EMS crews to bring patients to them with, for example, provision of refreshments. This generates income for hospitals in a system which is very different to that of the NHS in the UK. Adjusting triage rates does come at a cost. A US study (Xiang et al., 2014) proposed that in order to accommodate all patients who are currently under-triaged, trauma centres would need to increase their capacity by 51.5%. This is huge and, if extrapolated to the UK population, would have considerable impact on Emergency Departments

which in many cases are already operating at above their maximum capacity (Jones et al., 2022).

Waalwijk et al. (2021) found that there was a significant association between driving distance to a higher-level trauma centre, and under-triage in their study in the Netherlands where ambulances are staffed by nurses. The suggestion from this paper was that EMS clinicians used the driving distance, or travel time, as part of their decision-making process on transport destination, although it was not part of their triage protocol. This correlates with a US study (Holst et al., 2016) that showed that under-triage to a non-trauma centre was 35.6% in urban areas but 86.4% in rural locations. However, the geography of the USA means that some incidents could occur many hours travel from an MTC, and so direct transfer may not be appropriate from scene. The issue then arises around the timeliness of secondary transfers to specialist care. The issue here is more likely to be system design and access to services rather than on-scene triage performance. This study, based on national ED data, used death from trauma as an outcome measure. It is likely that transfer directly to the closest ED would be appropriate in a large number of these cases, either because additional help was required by the EMS crew to manage the patient, or their injuries were unsurvivable and the patient would not benefit from a longer transit to a trauma centre. EMS services in the US employ paramedics with different levels of training to the UK and also varying systems and protocols regarding recognition of life extinct (ROLE). It is therefore possible that many patients who were transported had in fact already died but that the attending crew were not authorised to cease resuscitation attempts (Sasson et al., 2009, Goto et al., 2013). Under-triage is not uncommon in physician staffed services though, highlighting the challenges in pre-hospital assessment by all types of clinician (Benhamed et al., 2020)

The ACS-COT recommended rate of an under-triage level of less than 5% is internationally accepted and utilised. However, it could be questioned whether there is a difference in outcome in systems that achieve this compared to those that do not. This was investigated by a US team (Jammula et al., 2018) who calculated under-triage as patients with an ISS>15 for whom a trauma team was not activated. They found no difference in mortality between the centres with ‘acceptable’ under-triage rates and other trauma centres. However, as discussed elsewhere, this is based solely on death as an outcome measure. Of perhaps greater consequence is patients who sustain disability, particularly if this may have

been prevented or lessened in severity. As pointed out in the NAO report (2010), returning trauma patients to high functioning status is important, not only for the patient and their family, but for the wider society.

The difficulty with ascertaining if a patient was under-triaged is highlighted by Bieler et al. (2018) who propose that this can only be calculated on an individual patient basis, after the hospital attendance. This does makes sense in that the need for specialist services may only be accurately assessed for each particular patient if one is referring to operations, ITU admission and specialty intervention. However, some of the other factors which are more challenging to quantify can include benefits obtained from for example, reduced time to definitive care due to a well-trained and efficient trauma team (Hong et al., 2019) or the psychological effects of being cared for by specialist trauma nurses (Crouch et al., 2015).

It is recommended that further work is undertaken to evaluate patients with an ISS<15 who received specialist care and also those with an ISS>15 who did not require intervention only provided in an MTC. This could help define more accurate outcome measures for which to evaluate trauma triage.

6.3 Demographics and characteristics of the study sample

This section discusses the results in relation to age and sex, comparing them with other studies and the UK trauma population. This allows consideration of the application of the study results outside of the Wessex region and their applicability in practice throughout England. Special considerations for defined groups (such as older people) are presented and discussed, with reference to the findings of this study and other published literature.

6.3.1 Age

There are issues at the lower and upper ends of the age ranges, both in researching trauma triage and in applying diagnostic tools to patients of all ages (2.7, 3.5.1, 5.1.3). Some tools do not perform as well in paediatric or older populations, with work continuing to improve this situation in the UK (Jarman et al., 2021, Chernbumroong et al., 2021). These groups of patients are discussed below.

6.3.1.1 Paediatric patients

The number of paediatric patients initially identified for this study was small (n=75) which prevented any meaningful statistical analysis (5.1.3), in particular, when carried out in relation to variable 'normal' physiological values. This is in line with other studies (Chapter 2) which have also not specifically dealt with paediatrics as a subset. The Wessex TUB tool was one of a number of prehospital trauma triage tools which was evaluated using data from four English hospitals (2 MTCs and 2 TUs) (Ardolino et al., 2015). These data were retrospectively applied to each of the tools selected and the accuracy in predicting ISS > 15 calculated. The authors note that for paediatric patients with moderate to severe injuries, current triage tools result in over-triage whilst those with minor to moderate injuries are more likely to be under-triaged. This is of concern in that a proportion of children will not be transported to the centre appropriate for their clinical needs. In particular, paediatric ITU services tend to be focused in larger units (such as UHS) and so transfers may be required earlier or more frequently than for adult patients.

The challenges of assessing accuracy of triage tools in the paediatric population is described in the literature (Newgard et al., 2005, van der Sluijs et al., 2020, Huang et al., 2019, Lerner et al., 2017). All of these studies have found that triage tools used in their respective areas performed badly in identifying children who required specialist trauma services. There may be a case that these patients are managed differently and that clinicians do not try to apply generic tools to a diverse population.

One suggestion would be that all children who suffer trauma and require ambulance attendance are transported to a major trauma centre. This may happen informally in some cases already (Hannon et al., 2013) although appropriate BPT reimbursement is not always achieved (Fontalis et al., 2020). Given the frequency of paediatric trauma calls (Naqvi et al., 2016), this could help to focus skills, knowledge and experience of clinicians in specialist centres, most of which are also adult MTCs and so have systems in place to manage major trauma. For example, paediatric trauma surgery, particularly in younger children, is carried out less frequently than in the adult population and so centralising these cases can improve mortality and morbidity (Deasy et al., 2012). One of the main disadvantages of this approach includes the 'de-skilling' of staff in trauma units (Beeharry and Moqeem, 2020). This could be particularly problematic when children are brought to hospital

by private transport, rather than EMS provider, and staff and systems are not equipped to manage the child and their injuries. As children are generally smaller, they can often be picked up and transported more easily than adults and, particularly in rural locations, parents and carers may elect to do this rather than wait for an ambulance to attend (Thinnes et al., 2020, Huber et al., 2016). Another consequence of transporting all injured children to MTCs is that this may be some way from home for families and can cause distress and inconvenience for patients and their families (Naqvi et al., 2016) with children having specific psychosocial and educational needs (Ardolino et al., 2012). Therefore, it can be seen that the approach to major trauma triage for adults may not be directly transferable to children.

6.3.1.2 Older patients

Whilst older patients may differ from younger patients in the mechanism and pattern of injury, the results presented here do not support a recommendation for a separate triage tool for this group.

In this study (5.1.3) 44.9% of patients were 65 or over and of those, 32.9% had an ISS of greater than 15 compared to 35.8% of the under-65 age group. However, the proportion of under-triaged patients who are over-65 (19.6%) is much higher than the younger group (14.56%). This correlates with the issues described in the literature around identifying those older patients who have suffered major trauma using the triage tool.

As highlighted in 4.2.2 the over 65-year-olds represent 14% of the population of Southampton, compared to the national figure of 18.2%. This demonstrates that this group are disproportionately represented in the trauma population with over 40% been shown in this study and the whole of England study by Moran et al (2018) and so major trauma can no longer be considered a disease of the young.

TARN released a major report on major trauma in older people (TARN, 2017) which highlighted the increase in older people suffering major trauma and the move away from traditionally male predominance in this patient group. They also noted that traumatic brain injury is the commonest cause of death in older people who sustain trauma, and that the commonest mechanism of injury is a fall of less than 2 metres in comparison to road traffic collisions in younger patients. The incidence of disability in patients who survive is higher for older people and the death rate rises

steeply in the first-year post injury which needs to be taken into account when assessing outcomes. Of note, they highlight a need to undertake further research around the effect of frailty on recovery from traumatic injury.

The issue of prognostication of major trauma patients in this group may be influenced by assessments of frailty and location in which the trauma occurred. Hendrickson et al. (2015) found that severe injury inside the home could be linked to frailty and subsequently outcome. When considering outcomes for very old patients, factors other than physiological and anatomical injury may be considered in the very severely injured. For example, a very frail patient with multiple comorbidities with a severe head injury and low GCS, may be considered for palliation more rapidly that a much younger patient who may be more able to undergo surgical intervention with a reasonable quality of life being the aim of treatment. This raises complex ethical issues around end-of-life care and when decisions on ceiling of care should be made following trauma (Owens, 2012, Fokin et al., 2020). Whilst prehospital providers are experienced in dealing with end of life care, it is unlikely that ceilings of care in the context of major trauma would be made in this phase (Myall et al., 2020). However, ambulance clinicians can provide important collateral history to assist in making decisions around appropriate care, including bringing ‘do not attempt resuscitation’ documentation where available to the receiving hospital and noting details around the patient’s social situation and mobility.

The early identification of older trauma patients who are severely injured or who have a high chance of significant morbidity, could be improved before ambulance crews arrive on scene by addressing the initial telephone assessment. At least one English ambulance service has a formal project related to this underway (Faqir, 2018), having identified that calls that are coded as falls can wait up to 90 minutes for a call back to be further assessed. This can result in substantial delays in ambulance despatch, arrival on scene and transport to hospital. The need to consider comorbidities and medications (particularly anti-coagulation) is highlighted, not to mention the issues of comfort and dignity around an older person not being able to get themselves up following a fall.

Interestingly, when looking at physiological variable for both age groups (5.2), there is little difference in the mean values for heart rate and respiratory rate. However, the median systolic blood pressure in the elderly patient group is 152mmHg

compared to 128mmHg in the younger group. This is likely to be due to the incidence of hypertension in older patients compared to those under-65 but is also likely to be affected by prescribed medication. Therefore, different parameters for what constitutes ‘normal’ may need to be considered. This is described in a paper from the USA (Oyetunji et al., 2011) which analysed over 900,000 emergency department trauma patient’s records. They found that the classic definition of hypotension being a systolic blood pressure of less than 90mmHg was optimal when assessing patients under 65 but should be increased for those older than this (in the region of 117mmHg). This is important when applying any physiological scoring systems or decision support tools to adult patients of any age as clinicians may not appreciate the presence of hypoperfusion or hypovolaemia.

In this study, the sensitivity and specificity of the TUB tool varies by age (5.5.1). If the systolic blood pressure threshold was adjusted to less than 120mmHg (in line with the Oyetunji et al. (2011) study), rather than 90mmHg, sensitivity in predicting major trauma would only increase from 40.5% to 45.1% with a much larger drop in specificity (67.9% to 58.3%). Therefore, the creation of a new tool to incorporate an age adjusted blood pressure cannot be recommended at this stage.

There is an issue with using an arbitrary cut-off in age (which is based on the previous age of retirement in the UK). There are likely to be large differences in physiological reserve in a patient who has just turned 65 and is fit and living independently, compared to a patient of 90 years old who may be very frail. In addition, some patients who are younger can be frail or suffer from significant illness and so may not be appropriately affiliated with the younger group. Scoring systems are in use to measure frailty in major trauma patients to address these points (Jarman et al., 2021). It may not always be possible to ascertain a patient’s age at the scene of an incident if they have a decreased level of consciousness and there is not available collateral history (this of course also applies to the paediatric population when trying to understand if a teenage patient is an adult).

A recent systematic review (Alshibani et al., 2021) found that not only were older patients under-triaged but, when they were correctly triaged, they were still less likely to be transported to a higher level trauma centre or be transported by HEMS than younger patients. It has also been observed in a UK MTC that older patients are less likely to be initially managed by a full trauma team with a consultant present than younger patients with similar severity of injuries (Hoyle et al., 2020).

There needs to be a recognition that older patients are frequently under-triaged. The addition of consideration of frailty or co-morbidity should be considered in future modelling as described by Jarman et al. (2021).

6.3.2 Sex

Whilst no recommendations are presented here in terms of varying triage between male and female patients, it is of interest to note the differences in these groups in terms of major trauma presentations. This could be of particular use in targeting of accident prevention strategies.

A pivotal report by the National Confidential Enquiry into Patient Outcome and Death in 2007 (NCEPOD, 2007) found that 75 percent of trauma patients were male. Moran et al. (2018) demonstrated that the proportion of major trauma patients in England that were male declined from 68% in 2008 to 61% in 2017. Therefore, major trauma can no longer be seen as a disease of predominantly young men.

In this study, 59.5% of all patients were males, however, the proportion rose to 67.5% in the ISS>15 group compared to 55.3% in those with an ISS less than 15. (5.1.2). The age of each gender group varied with the mean age of male patients 52.4 years compared to 68.5 for the female group.

Other studies have found difference in patterns of injury and outcomes from trauma between male and female patients (Pape et al., 2019, Wohltmann et al., 2001, Joestl et al., 2019). The analysis of the data from this study (nor the wider literature) that suggests that initial triage should vary for men and women. It is of note however that the female group tends to be older (5.1.3) and so any changes based on age will affect the female cohort more than the males.

Pregnant patients were not considered in this study (data were not collected but numbers were likely to be very low), however, there should be considerations of this group, particularly when involved in motor vehicle incidents where restraint systems may cause injury to the foetus or reproductive organs. Pregnancy can increase the risk of domestic violence and trauma prevention strategies should include this (Leneghan et al., 2012). Trauma guidelines exist and expert, specialist help must be sought in these cases with the focus being on initial resuscitation and stabilisation of the mother (Irving et al., 2021). Therefore, triage systems should ensure that patients are transported to a hospital with obstetric services and that an

appropriate pre-alert is made to the receiving hospital to ensure the trauma team is augmented with an obstetric team if required.

6.4 Presence of major trauma

This section considers the outcome measure of ISS>15 used in this study to signify presence of major trauma and discusses some of the limitations. Section 6.4.1 describes how only patients who are TARN eligible have an ISS assigned and that this may exclude some important groups from research. It is proposed that, for future work, more sophisticated outcome measures are utilised to identify patients that would benefit from transport to an MTC rather than a Trauma Unit. These are considered in sections 6.4.2 and 6.4.3.

6.4.1 Patients not included in TARN

Some patients are not included in TARN data collection and so this may affect any analysis using these data. However, one of the strengths of this study is that it also included patients in whom major trauma was suspected but later not found. However, there are a cohort of patients who are severely injured who do not appear in TARN and so therefore do not have an ISS assigned. This may reduce the accuracy of data analysis. Two significant categories of these patients are described below.

6.4.1.1 Deceased patients

A number of studies in the review of the literature (Chapter 2) use additional means of evaluating the need for specialist trauma services, including intensive care admission and death. The latter is an important cohort of patients who are excluded from TARN data if they died en route to hospital. Whilst these patients may have died anyway due to the severity of their injuries, there are a number of key, emergency interventions (such as thoracotomy) which can improve outcomes in this situation which may not be available in all settings (Lockey et al., 2013).

Of the study sample, 12 patients were in traumatic cardiac arrest on their arrival in hospital. Of these, 6 had an ISS>15, 2 were ISS<15 and 4 did not have their ISS calculated. It can therefore be seen that the simple definition of ISS>15 may not be the most useful as it can exclude patients with very severe injuries. An example of this may be an isolated stab wound to the heart, causing exsanguination. As an

isolated injury, it would likely score less than 15 but of course is catastrophic and could readily result in death.

Of note, the Wessex TUB states, ‘consider going to nearest ED if cardiac arrest imminent’. This supports ambulance crews to decide to seek additional support in a hospital environment, even if it is not designated to accept major trauma (for example a local receiving hospital). In the UK, there is not an expectation that there will be an Emergency Medicine Consultant on site in hospitals that are not MTCs (RCEM, 2018), and so these extremely severely injured patients may be managed by more junior staff during the out of hours period, in addition to not having access to specialist services and systems to manage major trauma.

Cardiac arrest following trauma has traditionally been understood to have a poor prognosis (Lockey et al., 2006). However, later studies described in Baranard et al. (2017) show that survival to discharge can be as high as 8% of all cases and their own work that found short-term survival of TARN eligible patients in the UK survival of 7.5% was achieved. They recommend early and aggressive management of this group of patients to achieve positive outcomes. Emergency techniques, performed in the early stages of cardiac arrest such as resuscitative thoracotomy have shown success (Paulich and Lockey, 2020) when performed both in the pre-hospital and emergency department environments by non-surgeons. There is a recognition that conducting high quality research on this procedure is challenging (Tabiner, 2019). It is possible that a number of those patients who were recorded as being in traumatic cardiac arrest on arrival in the ED were in fact in a ‘low-flow state’ or ‘pseudo-pulseless electrical activity (PEA)’(Rabjohns et al., 2020). Therefore, such patients may have responded to fluid resuscitation with blood products (Spahn et al., 2019) and damage control surgery (Ntourakis and Liasis, 2020) in a way that a patient who had in fact died would not.

Further research to identify this group of patients and suitable strategies for management (e.g. reducing on scene time versus interventions on scene and selection of destination – nearest ED versus MTC) may improve survival rates further. The provision of enhanced care teams at the scene of an incident may improve access to specialist services such as emergency surgery and blood transfusion.

6.4.1.2 Length of hospital stay of less than 72 hours

It is possible that there is a cohort of patients who received significant injury, for example penetrating chest injury, but did not stay in hospital for over 72 hours and were therefore not eligible for entry into TARN. If surgery was carried out rapidly, with favourable results and no complications, in an otherwise fit and healthy patient, it is possible that they may have been discharged. Pallett et al. (2014) demonstrated that, in a London MTC, the length of stay following admission with injuries associated with knives, had a vast range (1 to 48 days). Also, given that some of these patients may have been involved in interpersonal violence, they may have self-discharged against medical advice and not be counted in the numbers. This may be more likely in younger patients with a chaotic lifestyle or substance misuse problems. This phenomenon has been studied by Jaspere et al. (2020) although, as this was a study from the United States, the greatest predictor of self-discharge was lack of insurance and so there is limited applicability to the UK population which benefits from healthcare which is free at the point of access. This group of patients is likely to represent only a very small number of patients who may have been severely injured but not recorded for TARN purposes.

6.4.2 Presence of major trauma

Of the 1035 patients included in this study, 34.5% (n=357) had an Injury Severity Score of 15 or over and were therefore assigned to the ‘major trauma’ group or described as ‘disease present’ for the purposes of analysis the accuracy of the Wessex Trauma Unit Bypass Tool.

As described in the review of the literature (2.5) the majority of papers evaluated used a definition of major trauma which included an ISS of 15 or greater. However, ten studies (Rehn et al., 2009, Tamim et al., 2002, Brown et al., 2011, Cox et al., 2012, Cox et al., 2011, Dinh et al., 2014, Dinh et al., 2012, Henry, 2006, Lavoie et al., 2010, Lin et al., 2012) used additional or complementary measures in an attempt to more accurately capture patients who could be deemed to have suffered major trauma. These included requirement for emergency surgery, admission to an intensive care unit and death in the hospital. The question of how best to assess major trauma in an attempt to either triage, prognosticate or analyse has been repeatedly addressed, often with a view to developing and validating new tools or scoring systems.

Roden-Foreman et al.(2017) suggest that patient's trauma burdens are a combination of the anatomical damage sustained, the physiological derangement which results from this and the subsequent depleted reserve. ISS addresses anatomic injury whilst the Revised Trauma Score defines major physiologic derangement. Their new score, the modified Need for Trauma Intervention (NFTI) (Table 6-1) identifies severely depleted reserves and combines this with emergency interventions (including blood transfusion, emergency surgery or interventional radiology, ITU admission and mechanical ventilation) and/or early mortality. They utilised a range of outcome measures to assess the patient's condition including discharge to a care facility rather than home, complication associated with injuries and length of hospital stay. Although they found that ISS and RTS were positively associated with these outcomes, the NFTI did outperform both established scoring systems. The NFTI is now used in some trauma systems to retrospectively review cases and identify over-triage (Harrell et al., 2020, Shahi et al., 2021) with demonstrable success.

The MATTS study team (2.9.2) have recently published their work around building a consensus-based definition for the UK to define patients who would benefit from major trauma care (Fuller et al., 2021a). They held a facilitated roundtable expert consensus meeting of 17 clinicians and then used focus groups to gain public and patient involvement in the process. They established four reference standards:

- need for critical interventions
- presence of significant individual anatomical injuries
- burden of multiple minor injuries
- important attributes

The second and third points address some of the weaknesses of ISS in that one large injury could score highly and also the cumulative effect of multiple injuries (or polytrauma) is considered. The patient attributes section considers patients who may not benefit from trauma unit bypass due to the presence of severe frailty or where they have an advanced directive in place. It also recognises futility for patients with unsurvivable injuries or prolonged cardiac arrest. These findings are in concordance with the points made in this thesis and demonstrate the importance of this research as it is being addressed at a national level with considerable resource. The MATTS team have developed a coding algorithm utilising these

standards which can be operationalised within TARN to classify cases as requiring MTC care.

It could be argued that each system should decide what factors are important to them, for example under-triage, use of resources, volume of secondary transfers, length of stay, etc and then evaluate the performance of their triage tool in identifying patients that fit these requirements. This could mean for example in a system willing to accept larger numbers of secondary transfers, a tool is more likely to direct patients to a TU rather than an MTC. Several factors could affect this decision, for example skills and facilities in the local TUs, distance between TU and MTC, availability of ambulance transport for primary (from the scene) and secondary transport.

However, in reality, it may be that systems are trying to best identify the patients that will attract best practice tariff (BPT) – funding for trauma patients to the MTC. Current BPT is paid on patients of ISS of 9 or above (level 1) or ISS of 16 or above (level 2), conditional on certain factors (NHS England, 2021). Therefore, for an MTC to maintain a functional system, it must attract these payments by appropriately identifying and managing these patients.

6.4.3 Other measures of need for MTC care

Whilst many papers in the literature have utilised ISS>15 as an outcome measure for major trauma, other studies have solely used in-hospital mortality or survival to 30 days.

Whilst ISS>15 is problematic in terms of accurately recognising patients who require specialist services, mortality is a rather blunt instrument. It could be argued that many patients who die within the first month of being injured were so severely damaged that they may never have been able to survive. This is particularly of relevance in the ‘unsurvivable head injury’ group where the initial insult was too great to ever make a meaningful recovery from (Dixon and Malinoski, 2009). Many patients who exsanguinate do so in the first few moments following injury (Sobrino and Shafi, 2013), particularly if a large vessel is involved such as in traumatic aortic dissection. This cohort of patients are likely to die even before EMS arrival and most likely before surgical intervention can be achieved (Gunst et al., 2010).

There is also a cohort of patients who, although they have multiple injuries, may appropriately be managed in a Trauma Unit in the initial phase and transferred for

specialist surgery once they are more comfortable and stable. Therefore, it is the patients in the middle of these groups that we must accurately identify; the ones who can be ‘saved’ or optimised by specialist teams and require interventions that are not available in TUs.

There are particular specialties which are concentrated around MTCs. This includes neurosurgery, cardiothoracic surgery and interventional radiology. These services cannot be provided at the TUs in the same way and so if a patient needs these urgently, they must be seen at an MTC as soon as possible. An example of this would be a traumatic brain haemorrhage where the haematoma needs evacuating urgently, to avoid it damaging the brain further. Injuries to the great vessels in the chest and for example cardiac tamponade are also time-critical emergency procedures. Interventional Radiology can provide control of bleeding in a minimally invasive fashion with excellent results and is carried out by specialist Radiologists. However, some of these patients, for example the head injured patient who cannot maintain their own airway or the haemorrhaging patient who is peri-arrest, may be taken to the nearest TU as they cannot be safely managed by ambulance personnel. This is one of the key arguments for providing enhanced critical care, usually physician-delivered, in the pre-hospital phase. They may be in a position to stabilise a patient in order to undertake a longer transport to definitive care.

Although these specialist services are often described when discussing need for MTC, there are also the less tangible benefits of being seen in a centre that routinely cares for severely injured patients. Additional roles such as trauma practitioners can co-ordinate care from multiple specialties and provide support to patients and families as they manage their hospital stay and consequences of injury (Crouch et al., 2015). MTCs are likely to have robust systems for managing trauma patients and to have focused education of teams to manage these patients. For example, a high functioning trauma team will be able to assess, resuscitate and transfer a patient to CT, ITU or theatre in a more timely fashion than a team which does not regularly practice this or have the systems in place to liaise with other specialties. This can reduce time to imaging (a BPT measure) and damage control surgery. Critical Care teams will also be more used to supporting trauma patients than in centres where these patients are seen less frequently. Therefore, using simply a measure of ‘emergency surgery’ or ‘need for intervention’ does not adequately capture the need for MTC care.

6.5 Effect of physiological values on triage

The analysis of this data set included not only the physiological variables included in the TUB tool (respiratory rate, systolic blood pressure and GCS) but also other commonly recorded values (heart rate and oxygen saturations). As discussed, there was little difference in mean and median values between the major trauma patients and non-major trauma patients for most vital signs. The only observation which provided a useable difference between the two groups was Glasgow Coma Score. However, this value is different from all of the others in that it is calculated by the clinician rather than objectively recorded, either manually or mechanically.

6.5.1 Respiratory rate

There was no statistically significant relationship between respiratory rate and presence of major trauma found in this study. When the threshold of the respiratory rate variable was changed to >25 rather than >29, sensitivity improved (57.7% compared to 51.3%) but specificity worsened (61.1% from 63.7%). However, inaccuracies were found in the data set. For example, the range of respiratory rate recorded was 0 to 90. This suggests either a data entry error on the electronic patient record, illegibility on a paper record or transposition with the oxygen saturations or heart rate. This has introduced some error into the data analysis and will have falsely elevated the mean calculated as described in 5.2.

Respiratory rates are documented less well often than other vital signs, particularly in the emergency setting (Parkes, 2011, Flenady et al., 2017, Elliott and Baird, 2019, Lovett et al., 2005, Philip et al., 2015). Whilst work has been carried out to understand the accuracy of recording of respiratory rate by nurses, there is very little relating to the paramedic profession or pre-hospital providers.

Lord and Woollard (2011) were able to demonstrate a small but statistically relevant correlation between respiratory rate and pain scored by patients assessed by paramedics. The causes of pain were caused by traumatic and medical or surgical causes and so the sample is not directly comparable, but it does show that there is a link. It may be the case that pain causes the patient to breath more quickly and so it may be a less useful indicator of injury or illness than may be thought. Psychological stress can also influence respiratory rate (Raux et al., 2006). However, it should be noted that the Wessex TUB tool requires '***sustained*** RR<10 or >29' which should account for changes caused by pain or anxiety. It is

also a limitation of the study in that multiple sets of observations were not recorded in the data set and so it was presumed that any respiratory abnormality noted was sustained.

A study including over 12,000 cases in the US (Yonge et al., 2018) demonstrated that tachypnoeic patients were more likely to be under-triaged in the pre-hospital setting and also were more likely to have a flail chest or require a chest drain compared to patients with a normal respiratory rate. The authors of this study evaluated a modification to their triage tool which included tachypnoea (rate over 20) but this produced unacceptable rates of over-triage. However, when combined with 'suspected blunt thoracic injury" they were able to reduce the under-triage rate from 5.9% to 4.7%. This combining of triage tool components will be discussed later (6.6). The majority of patients who suffer a traumatic brain injury (TBI) present with a normal (10-29 breaths per minute) respiratory rate although those with an abnormal rate have significant mortality (Pearson et al., 2012). Hypoventilation may be seen in severe TBI or spinal cord injury as opposed to many other injuries where hyperventilation is more likely to be a factor. This again highlights the difficulties of trying to produce a triage tool which is suitable for all types of trauma.

Although the literature suggests respiratory rate can be abnormal in major trauma, there is a lack of correlation between respiratory rate and ISS>15 in the study presented here. For this reason and the difficulties in accurately measuring it, no change to the TUB tool thresholds for this variable is suggested.

6.5.2 Blood pressure

The findings of this study (5.8.2) were that systolic BP did not have a statistically significant correlation with ISS>15 and the same was true for the 'trigger' of SBP<90mmHg. In the modelling of altering physiological thresholds (5.8.3), changing the cut off for hypotension to less than 100mmHg improved the sensitivity of the tool from 51.26% to 59.4% with only a small reduction in specificity from 63.72% to 63%. This would suggest that this single change could produce an improvement in accuracy of the tool for all adult patients. If the threshold was changed to <110mmHg as suggested by Hasler et al. (2011), the sensitivity improves further to 63.59% but with a reduction in specificity to 59.14%.

A systolic blood pressure of less than 90mmHg is used in the Wessex TUB tool to identify hypotension or, more specifically, estimate hypovolaemia. This is a

common figure to select for this purpose and is used in Advanced Life Support (ALS) training (RC(UK), 2021). A UK study, utilising TARN data from a period of 9 years, sought to investigate the association between systolic blood pressure and 30-day mortality in patients who had sustained blunt trauma (Hasler et al., 2011). They found that a more accurate cut off to identify hypotension was 110mmHg and that mortality rates doubled at <100mmHg, tripled at <90mmHg and were 5-6 fold at <70mmHg, independent of age. Whilst it is not clear if this refers to a sustained blood pressure, and it is not stated if this was measured in the pre-hospital or in-hospital phase, it does make for interesting consideration. Of importance is that the study population excluded patients with head trauma. This has been discussed previously (5.8.3) and others have suggested that this triage tool component should be altered in cases of TBI (Thompson et al., 2017) due to differing hypotension thresholds being required to avoid increased morbidity and mortality (Spaite et al., 2017).

A risk to relying on blood pressure readings to identify major trauma is the accuracy of measurement. A US study of major trauma patients (Davis et al., 2003) was able to demonstrate that automated machines consistently gave values higher than recorded by manual means in this group of patients. Automated machines are routinely used in UK pre-hospital and emergency department practice so it is possible that clinicians are falsely reassured by the values presented to them. This paper recommends that values are correlated by manual means when the SBP is less than 110mmHg although this may provide practical challenges, in particular when in a noisy, moving ambulance en route to hospital.

The issue of assessing blood pressure in older patients is discussed in 6.3.1. A large study by Brown et al. (2015) advocates altering the threshold for the US National Trauma Triage Protocol for patients over 65-years old from <90mmHg to <110mmHg. The effects of this change on the Wessex TUB tool for this population is demonstrated in 5.8.3. The sensitivity of the tool could be improved with increasing the systolic blood pressure and it is recommended that, to achieve an acceptable trade-off between sensitivity and specificity, testing in practice is undertaken with a new threshold of BP<100mmHg.

6.5.3 Glasgow Coma Scale

The Glasgow Coma Scale trigger (motor score of 4 or less) was the only TUB tool variable shown to predict ISS greater than 15 (5.8.2). However, neither a total

score nor individual components achieved this independently. However, if the GCS trigger was changed to GCS less than 14 (i.e. 3-13) in line with the US National Trauma Triage Protocol (McCoy et al., 2013), the sensitivity improved from 51.26% to 56.86% with a reduction in specificity from 63.71% to 62.24%.

Assessment of the GCS can be difficult in the emergency situation, and interrater reliability is poor (Gill et al., 2004). Simplifying the assessment of conscious level to only assessing the patients ability to follow command was suggested as a means to enhance triage of trauma patients in the 1990s (Meredith et al., 1995), particularly as it could be utilised by first responders who may not have the clinical skills of paramedics. This was later correlated in a further study with a large sample size from two centres (Hopkins et al., 2018).

It can be seen therefore that, although assessment of GCS can be more challenging than for physiological parameters which are read by a machine, it is useful in identifying patients who have suffered severe injury, in particular a traumatic brain injury. Although this study suggests that changing the GCS component from simply a motor score, or unable to follow commands in its more simplistic form, that a combined eye, verbal and motor score may improve the sensitivity of the tool.

Again, this highlights the fact that the tool is designed to identify all types of severe trauma but that patients with traumatic brain injury present differently to those suffering primarily from hypovolaemic shock through external bleeding or into a body area other than the head. No change in GCS for patients with hypovolaemic shock was found by Guly at el. (2011) in a UK study using TARN data. A challenge of the tool is to capture this range of physiological values with an acceptable rate of over-triage. However, as demonstrated in 5.7 the simple composite of GCS, age and systolic blood pressure performed poorly utilising this data set with the sensitivity being 30.81%.

The findings from this study support a recommendation to trial altering the GCS threshold to total GCS less than 14.

6.5.4 Heart rate

Heart rate, or pulse, is not currently included in the Wessex TUB tool. In this sample, it did not have utility in predicting major trauma OR 1.00 (p 0.384). When comparing those patients who had suffered major trauma to those who had not, the

mean pulse was 85.2 compared to 84.0. The mean heart rate of patients who were under-triaged was 85.3, compared to 84.4 in the entire sample. This suggests that tachycardia is not an indicative factor in patients who suffer major trauma. This is in contrast to a UK study of TARN eligible patients (Guly et al., 2011) which demonstrated a trend to increasing heart rate with estimated blood loss. However, even in class 4 shock (by ATLS definition) which is 40% loss of circulating volume, the median heart rate was below 100 and so within normal range. If an additional variable of heart rate >100 beats per minute were added to the TUB tool, the sensitivity would improve to 60.5% but specificity would reduce markedly to 52.4%.

Kim et al. (2021) were able to demonstrate an association between a heart rate over 90 and increased mortality of trauma patients, but only in the over 85-year old age group. The effect of medications frequently prescribed to older people, such as beta blockers, may further confound assessment by preventing the patient from mounting a compensatory tachycardia. This concept of haemodynamic compensation is also discussed by Cooke et al. (2006) with reference to their pre-hospital study. They found that heart rate variability did not predict mortality in trauma patients but that narrowed pulse pressures (the difference between systolic and diastolic blood pressure) when considered in the context of response from the autonomic nervous system (indicated by tachycardia) was associated with death. However, their findings did not have immediate translation into practical clinical practice in the pre-hospital environment. Kumar et al. (2019) undertook a small but novel study whereby they evaluated the utility of electrocardiograms (ECGs) from major trauma patients in predicting the need for life-saving interventions. Whilst their new score did perform better than other established scores, including T-RTS, MEWS and MGAP/GAP, it was not useful in the emergency setting. Although they did use a common defibrillator with ECG capability (Zoll X-series, used widely in the Wessex area), they used additional software to evaluate the ECG component of the vital signs. Given that their aim was to identify need for life-saving, (and by inference time-critical) interventions, it is difficult to see how this could be practically useful in the immediate phase of care.

From the findings presented in this thesis and the relevant literature, it would appear that the addition of heart rate to the TUB tool would not improve performance in identifying major trauma patients.

6.5.5 Combining vital signs

In addition to evaluating the Wessex TUB Tool, this study also compared its performance to two common, and easily calculated trauma scoring systems (5.7). Both GAP and T-RTS had high specificity but sensitivity was very low (Table 5-10) and therefore they cannot be recommended as substitutes for the TUB tool. Other score combination methods, and shock index, warrant further investigation for use within a new tool.

6.5.5.1 GAP

The GAP scoring system uses GCS, patient age and systolic blood pressure, giving a numerical result which then falls into one of three risk categories. GAP was found to have a sensitivity of 96.9% in predicting in-hospital mortality in an Iranian study that used data from patients involved in road traffic collisions (Rahmani et al., 2021). However, of 2570 patients included in the study, only 14 died. Moreover, predicting death is not comparable to predicting ISS >15 or need for specialist services and so the results are less relevant to this thesis. Kondo et al. (2011) had a much larger, multicentre data set from Japan and compared GAP with MGAP. They carried out extensive evaluation of these tools for use in the ED setting but again the outcome was in-hospital mortality. They found that GAP performed well against other scores, including TRTS, and it was easier to calculate. The area under the curve (AUC) of GAP as evaluated in an Iranian study (Mahnaz et al., 2019) was 0.91 (compared to 0.67 presented here – 5.6) but again the outcome measure was discharge alive rather than ISS>15. A further Iranian study (Rahmani et al., 2016) contained an additional outcome measure of ‘need for surgery’ for which the AUC was 0.74 for GAP. The surgical interventions included were laparotomy, chest drain insertion, craniotomy, spinal column and orthopaedic procedures. Whilst this more closely mirrors the aims of the TUB tool in identifying severely injured patients, it excludes for example interventional radiological procedures and patients who require observation and optimisation on Neuro ITU but not a craniotomy. Various cut-off values have been used to indicate a ‘high’ score; it is generally accepted to be 19 (Ahun et al., 2014) but has been altered to improve sensitivity to 18 in at least one study (Mahnaz et al., 2019) The results from this study though are closer to the findings presented in this thesis. Of note, the Indian study (Warnberg Gerdin et al., 2020) compared GAP, Revised Trauma Score, the Kampala Trauma Score and clinician judgement and found that

clinicians performed comparably to all of the tools in predicting in-hospital mortality. Again, this relates to identifying the sickest patients which arguably is more straightforward than trying to predict ISS.

Table 6-2 Performance of GAP trauma triage tool

Study	AUC	Sensitivity	Specificity	Outcome
Wessex TUB tool	0.66	30.8%	92.9%	ISS>15 (cut-off value 19)
Rahmani et al. (2016)	0.74	75%	57%	Need for surgery
	0.84	88%	85%	Death in ED
	0.99	98%	91%	In-hospital mortality
Mahnaz et al. (2019)	0.91	72.9%	95.52%	In-hospital mortality (cut-off value 18)
Ahun et al. (2014)	0.91	83.3%	87.5%	In-hospital mortality (cut-off value 19)
Warnberg Gerdin et al. (2020)	0.91			30-day mortality (cut-off value 19)

The current literature and analysis from this study does not provide any conclusions which can be used to recommend GAP as an alternative tool in the current UK population to identify patients with an ISS>15.

6.5.5.2 T-RTS

The Triage-Revised Trauma Score is a composite of coded values assigned to normal and abnormal ranges of values for GCS, SBP and respiratory rate (3.8.2). It is similar to systems in common use in the UK (NEWS, MEWS, NEWS2) in that actual values are placed in a range, scored and then combined. This can be built in to triage systems and electronic patient records which are now in widespread use in UK pre-hospital practice. For T-RTS, the maximal score is 12 but any score less than this has been taken to indicate need for transport to a trauma centre. This score can therefore be achieved with one ‘abnormal’ value in any of the categories. When this tool was tested with the Wessex data, the area under the curve demonstrated that the tool did not perform well. Whilst the specificity was reasonably high (87%), the sensitivity was poor (38%). Several studies (Table 6-3) have adjusted the cut-off value in an attempt to improve performance. However,

the converse was true for both Champion et al. (1989) in the original work on this tool and Covino et al. (2021) in a very recent study. The results from the latter is not comparable to the Wessex study as the outcome was markedly different but Champion et al. (1989) also used ISS>15 and achieved a higher sensitivity. It is possible that the trauma population in this US study from over 30 years ago is not comparable to the picture currently in the UK. Roorda et al. (1996) achieved the same result for sensitivity as the Wessex study when using ISS>17 as an outcome. The performance of the tool improved when evaluating against a higher ISS or need for emergency treatment. This again raises the issue of defining the correct outcome measure for trauma triage performance.

Table 6-3 Performance of T-RTS trauma triage tool

Study	**AUC**	**Sensitivity**	**Specificity**	**Outcome**
Wessex TUB tool	0.63	38%	87%	ISS>15 (cut-off 11)
Moore et al. (2006)	0.84			In-hospital mortality
Covino et al. (2021)	0.67	37.1%	96.7%	Death in ED or ITU admission (cut-off 11)
		13.2%	99.8%	Death in ED or ITU admission (cut-off 10)
		10.7%	99.9%	Death in ED or ITU admission (cut-off 9)
Champion et al. (1989)		59%	82%	ISS >15 (cut-off 11)
		49%	92%	ISS >15 (cut-off 10)
		39%	96%	ISS >15 (cut-off 9)
Roorda et al. (1996)		38%	94%	ISS >17
		56%	94%	ISS >19
		76%	94%	Emergency thoracotomy, laparotomy, neurosurgery, immediate admission to ITU or death within 48hrs

The performance of T-RTS was improved by Covino et al. (2020) by the addition of blood glucose level. This was particularly noted in patients over the age of 65 and uses a routinely collected variable. However, it adds another level to the calculation and therefore introduces greater opportunity for error. Their work would need to be translated for UK practice as differing units of measurements are employed in their Italian study to those used in UK ambulance and ED settings.

Lichtveld et al. (2008) found utility for the T-RTS not only in trauma triage but also recognising the deteriorating patient. They found that a reduction in the T-RTS during the transport phase was an independent predictor of mortality after hospitalisation.

Whilst the T-RTS is a simple tool, it would appear that it does not have utility in the current trauma population to be used as the sole means of triaging major trauma patients.

6.5.5.3 Other methods of combining variables

Reisner et al. (2014), building on the work of Cooke et al. (2006) previously described, found that combining GCS with heart rate and SBP improved the positive predictive value of their new tool in identifying high-mortality TBI. Although this study presents interesting findings around combining vital signs, they developed a multivariate model which is not easily useable in practice. However, with the increasing access to electronic patient records and other handheld technology, this could become part of an electronic or ‘app’ solution to trauma triage as previously described (Freshwater and Crouch, 2015).

An analysis of over 1.5 million cases in the US (Filipescu et al., 2020) evaluated the physiological variables GCS, HR, RR, SBP, SPO_2 and temperature, all measured in the ED, and then modelled various combinations of these variables. The outcomes were in-hospital mortality and ISS>15. Whilst each physiological value on its own did not perform well, the AUC improved in some of the combination models. They found that replacing SBP and RR in the RTS with shock index (HR/SBP) and adding oxygen saturations and temperature, improved performance across all ages. They increased the accuracy further by adjusting shock index for age. Although this study presents a large amount of modelling, it is aimed at improving on a score to be used in research and service evaluation rather than as a field triage tool. One potential limitation of this tool in the pre-hospital

environment would be the poor correlation between readings from commonly used tympanic thermometers and core body temperature (Skaiaa et al., 2015).

The shock index (SI) is an attractive proposition for a triage tool due to its simplicity. It is simply calculated by heart rate divided by systolic blood pressure. It is not intended for use solely in trauma, having utility for patients experiencing myocardial infarction, sepsis, and shock from other causes such as pulmonary embolism and ruptured ectopic pregnancy. A review of the literature around SI (Koch et al., 2019) found that for trauma patients in the ED setting, SI may be more valuable than isolated physiological variables, and did correlate with a need for massive transfusion, but it was not recommended as a triage tool. They described changes in SI being useful for identifying the deteriorating patient but that many patients initially compensated for their shock and so did not declare their condition on early presentation via the SI.

This limitation was identified by Wang et al. (2020) who attempted to adjust for this by substituting SBP for mean arterial pressure (MAP) which also accounts for diastolic blood pressure and so also reflects stroke volume and systemic vascular resistance which are affected by the autonomic nervous system in response to trauma. This was a pre-hospital study of 1007 patients in a single-centre but outcomes were limited to hospital mortality and need for massive transfusion of blood products. The result was that, although theoretically superior, the modified shock index did not perform any better than the existing SI and that it was more difficult to calculate in the pre-hospital environment. ISS >15 was used as part of the evaluation of SI in a study using TARN data (Bruijns et al., 2013) but the AUC was less than 0.7 (0.69) which is the minimum acceptable and so it was not useful in predicting major trauma.

Therefore, shock index, or a modified version of it, cannot be recommended as an alternative to the Wessex TUB tool. However, the substitution of SBP with SI was found to improve the performance of the American National Trauma Triage Protocol (Haider et al., 2016) in predicting ISS>15, need for emergent operation, death in ED or ITU stay > 1 day. Using a data set of over 500,000 patients, the sensitivity of the tool improved from 41.67% to 44.39% with the specificity reducing from 82.41% to 80.19%. They recommended further studies to explore replacing SBP of less than 90mmHg with a SI or more than 1. It is reasonable to consider carrying out this calculation on the Wessex data set too.

6.6 Pattern of injury

The mostly frequently triggered area of the TUB tool was ‘major pelvic fracture’, followed by open or depressed skull fracture. Very small numbers of patients had amputated limbs or spinal injury with paralysis.

When comparing patients in the major trauma (ISS>15) and non-major trauma groups, none of the anatomical injuries were statistically significant. This may partly be explained by the way that ISS is calculated in that one significant injury can score less than multiple less significant injuries. This adds to the argument for including ‘need for emergency intervention’ or ‘need for operation’ as outcome measures in assessing trauma triage tools. There are injuries which are included in TARN, and can be quite severe, such as significant facial fractures which are not included on the TUB tool. As these could have the added complication of threatening airway patency, they might be considered for TU bypass. Multiple limb fractures increase the score when assessed by TARN and so an older patient who falls, sustaining multiple stable rib fractures and bilateral distal radius fractures could score more highly than a patient with a single stab wound to the chest. Whilst both patients are likely to benefit from specialist care, the thoracic injury may have a higher mortality in the ED than the ‘silver trauma’ with multiple minor injuries. There are many more similar anomalies which can make defining ‘major trauma’ less straightforward that the definition provided by ISS>15.

However, the findings of the analysis of the under-triaged group show that anatomical injuries may have an influence on the ability to correctly triage patients. The relative lack of injures (including no pelvic or limb fractures) in the under-triaged group suggests that there may be a cohort of patients with a high ISS who do not have significant, obvious injury on initial presentation. A more detailed subset analysis of this group is recommended to ascertain the pattern of injury for these patients who are incorrectly identified as not having suffered major trauma. It may be that they have multiple less significant or noticeable injuries or that they compensate physiologically and do not present as being severely injured.

At the inception of the WTN, South West Ambulance Service Foundation Trust (SWASFT) used the same TUB tool as South Central Ambulance Service (SCAS) which meant that the Wessex TUB tool was also used across Severn and Peninsula networks. In 2020, SWASFT updated their tool and added clarification to

the pelvic fracture component. The Wessex TUB simply states ‘suspected major pelvic fracture’ but the SWASFT tool now adds the following qualifiers:

> *Suspected major pelvic fracture, where mechanism of injury is suggestive of a pelvic fracture AND is accompanied by any one or more of the following:*
>
> - *haemodynamic instability/signs of shock*
> - *deformity on examination*
> - *suspected open pelvic fracture due to bleeding PU, PV or PR (scrotal haematoma)*

This is useful for pre-hospital clinicians to assess for pelvic fracture requiring MTC management more accurately than the Wessex TUB.

One of the challenges of including anatomical injury in a pre-hospital triage tool is that in order for an injury to ‘trigger’, it must first be recognised by the assessing clinician. Infrequent exposure to trauma and environment factors such as darkness, cold and noise can all impede an accurate primary survey. Significant injuries can even be missed during the primary and secondary surveys once the patient has been admitted to ITU (Brooks et al., 2004). Point of care ultrasound is increasingly being used by pre-hospital critical care teams, particularly to identify chest injuries and intra-abdominal bleeding but a balance has to be found between delaying time on scene and identifying injuries, particularly in patients who are likely to undergo CT of the chest, abdomen and pelvis on arrival in hospital.

Some components of the TUB tool are simple to identify (amputated limb) but others less so. For example, suspected open or depressed skull fracture can be challenging to assess with boggy haematoma either masking or mimicking this type of injury. Others are open to interpretation, for example major pelvic fracture (as discussed above). There is also lack of clarity amongst clinicians as to what constitutes a long bone and how badly a limb has to be damaged before it is classed as ‘mangled’.

One suggestion would be to combine anatomical findings with physiological values. For example, suspected major pelvic fracture with haemodynamic instability. This correlates with NICE guidelines (NICE, 2016a) which advocates placing a pelvic binder if bleeding is suspected after blunt high-energy trauma. Chest injuries could be combined with respiratory rate and/or oxygen saturations and head injury of

course with GCS. It is therefore recommended that further work is undertaken to investigate the effect of combining anatomical and physiological variables.

6.7 Mechanism of injury

Many tools evaluated in other studies incorporate mechanism of injury (MOI) into field triage (Chapter 2). As mechanism of injury data was not reliably collected in this study, it is not possible to ascertain if the inclusion of MOI would improve the performance of the Wessex TUB tool with this study population.

Mechanism of injury can be described broadly, e.g. road traffic collision, or more narrowly, e.g. motorcycle versus car or patient ejected from vehicle. Broad categories can help identify mechanisms of injury that can be used at a system level or for prevention work and also to compare systems. Road traffic collision is the most common type of injury in many countries on different continents (Abbasi et al., 2013, Heim et al., 2014, Cameron et al., 1995, Soreide, 2009, Alberdi et al., 2014) but it is not clear if this then varies for example where bicycle use is more common or seatbelt laws are not in place. However, it is now possible that with an ageing population and major trauma more commonly occurring in the elderly, that falls could overtake motor vehicles as the predominant mechanism as they have in the UK (Kehoe et al., 2015).

Not only can the mechanism of injury be considered but also the consequences of this. For example, Nutbeam at al. (2021) demonstrated that patients that were mechanically trapped following a motor vehicle collision, were more likely to have spinal injuries than those that were not trapped. Therefore, it could be suggested that ‘patient trapped’ be used to assist with triage. However, the same study also found that these patients were also more likely to have deranged physiology than non-trapped patients. This demonstrates one of the conundrums of redeveloping a triage tool. Additional elements can be included in order to capture more patients; however, it also needs to be investigated if these patients would have been identified anyway due to ‘triggering’ on another part of the tool. A study carried out in Victoria, Australia (Boyle et al., 2008) found that although falls from greater than 5m were associated with significant injury, individual mechanism of injury criteria had no clinical or operational significance in pre-hospital triage in patients who had no physiological or anatomical abnormality. In other words, they would be identified by criteria other than MOI and so this section did not add anything to the triage tool.

Kondo et al. (2011) evaluated the GAP score against the M-GAP score where M is the mechanism of injury. In their large data set, GAP performed better than M-GAP which suggests that accuracy worsens when mechanism of injury is included.

Work has recently been carried out in UHS to evaluate the utility of mechanism of injury details in predicting ISS>15 and is currently being prepared for publication.

6.7.1 Blunt versus penetrating injury

Whilst not a mechanism per se, or a pattern of injury, use of the terms ‘blunt’ and penetrating’ to describe injuries is becoming commonplace. This can not only affect pattern of injury but also location within the body. For example, a study of autopsies from trauma patients (Dosios et al., 2000) found that different parts of the aorta were injured by penetrating injury compared to blunt and that of the former group, no patients made it to hospital alive which may be due to them also having other fatal intrathoracic injuries. The ability to manage penetrating injuries may also have a bearing on their high mortality when non-compressible areas of the body (great vessels, neck, etc) are injured compared to more diffuse bleeding patterns or injuries that are compressible for haemorrhage control.

TARN captures information on blunt and penetrating injury and so further work could be carried out to assess if combining this information with for example body part injured or physiological findings are more useful predictors of major trauma. It is recommended that consideration is given to evaluating ‘penetrating thorax injury’ as an anatomical variable.

6.7.2 Protective equipment

Whilst mechanism of injury may be considered as described above, it may be useful to consider the absence or presence of protective equipment, for example car seatbelt, cycle or motorcycle helmet, back protector in equestrian sports and specialist equipment in industrial settings.

A study from a London MTC showed that, in pedal cycle patients admitted with serious head injury, those who were not wearing a helmet were more likely to suffer subdural haematomas and skull fractures than the helmeted patients. Although this study was small, a later study (Dodds et al., 2019), using TARN data also showed lower rates of TBI in patients wearing helmets with an associated increase in need for neurosurgical intervention or ITU admission for those cyclists

not wearing a helmet. However, they did discover a statistically significant increase in chest, spinal and limb injury in the helmeted group although it is not clear how severe these injuries were in comparison to sustaining a TBI. As part of further work, it is recommended that the use of protective equipment is considered when analysing the utility of mechanism of injury information.

6.8 Clinical decision-making in pre-hospital trauma triage

Whilst this study is a quantitative analysis of the current system of trauma triage, there are some 'non-technical' issues that should be addressed. As previously discussed the use of ISS>15 to define major trauma can be problematic in identifying patients who would benefit from MTC intervention.

In addition, trauma triage is carried out by humans and therefore the tool needs to be useable by them and acceptable to clinicians (Cox et al., 2014, Gage et al., 2012, van Rein et al., 2018b). The addition of formal 'clinician concern' components is discussed below although a comprehensive discussion of paramedic decision-making is outside of the scope of this project.

Since the Wessex TUB tool was developed for use on a smartphone (Freshwater and Crouch, 2015), the app has now been extended to include similar tools for use with directing patients with heart attack, stroke, pregnancy issues and aortic problems to the most appropriate specialist centre for their needs. This suggests there is a need for easy-to-use signposting for busy clinicians who are required to consider a number of pathways.

Many major trauma patients in the UK are attended to by enhanced critical care teams, frequently physician-led. Many of these doctors also work with major trauma patients in the hospital setting and are well versed with the working of the trauma networks and patients that benefit from specialist services. It is not clear if these teams formally utilise trauma bypass tools or if their decision making is less formal in terms of selecting transport destination. Further work could be carried out to evaluate the levels of under- and over-triage by physician crews compared to paramedics and non-registered ambulance clinicians.

Clinician discretion to over-ride all other components of a trauma triage tool are discussed in the literature (Chapter 2) and has been associated with over-triage (Brown et al., 2011, Lin et al., 2012, Newgard et al., 2011b). It could be important to

evaluate if this is the case in the UK and if there is commonality in patients who are over-triaged. For example, whether paramedics bring in their own biases or values when considering which patients require transport to an MTC (O'Hara et al., 2015, Reay et al., 2018). Paramedics in England have reported feeling that their professional judgement is undervalued by other professionals (Reay et al., 2018). As more paramedics move into specialist and advanced roles, often leaving ambulance services, it is important to consider the level of experience of ambulance crews in dealing with major trauma and that additional support may be required at this stage (Hörberg et al., 2017). Call volumes for all 999 calls continue to rise (Claridge and Parry, 2021) and it is possible therefore that a dilutionary effect takes place and paramedics attend fewer cases of major trauma than their predecessors did (O'Hara et al., 2015). If there is a more junior workforce in place, this may increase the need for decision support tools to provide assistance and reassurance to ambulance clinicians (Thompson et al., 2019).

The utility of paramedic judgement in prehospital trauma triage was specifically investigated by Mulholland et al. (2005) through a review of the literature. However, they were unable to draw any definitive conclusions due to lack of comparability of outcome measures for trauma triage (as previously discussed here) and the range of training, qualifications and experience of clinicians classed as paramedics in various countries. Their study recommendation was that further studies are undertaken to validate the ability of prehospital personnel to identify anatomic injury patterns in patients who have experienced blunt trauma. This is in keeping with previous arguments outlined here with regards the ability to identify injuries in the field.

A UK study describes paramedic clinical decision making in major trauma as protocol-driven, as opposed to more complex scenarios where additional patient factors such as social circumstances and comorbidities must be considered (O'Hara et al., 2015). There is an argument that decision support tools, whilst being viewed as guidelines rather than rules, can help reduce the cognitive load in highly stressful situations. Many ambulance staff work long hours, and it has been demonstrated that fatigue, particularly on nightshifts, can influence paramedic decision making (Bartlett et al., 2021).

Chapter 7 Summary and conclusions

This chapter presents a summary of the doctoral study findings and places them in the context of clinical practice. Strengths and limitations of the study are discussed, and recommendations made for further research and changes to the TUB tool. Finally, the approach to disseminating the work in this study is outlined.

7.1 Key findings

This doctoral study used data from a calendar year to evaluate the accuracy of the TUB tool in identifying patients with an ISS>15. Data completeness was high, seasonal variation was accounted for and both TARN eligible patients and those suspected of having major trauma were considered. The latter point is a major strength of this study when compared with others that solely use TARN data and so do not consider patients who were later found to have no or minor injuries.

The TUB was found to perform poorly in identifying ISS>15 (sensitivity 51.3%) which correlates with a previous evaluation of the Wessex TUB tool (Potter et al., 2013). The Wessex trauma triage tool has low accuracy when compared with other similar tools presented in the literature (Figure 6-1) although no other UK tools have been fully assessed to date. The specificity of the TUB tool was 63.7%. The trade-off between sensitivity and specificity has been explored and it is likely that, to improve sensitivity, specificity will decrease. These limits of acceptability need to be considered at a system level.

The rate of over-triage, i.e. patients being transported to an MTC when they have an ISS<15, was shown to be 36.3%. This is lower than in many systems described in the literature (2.7) but may be appropriate to preserve resources in a public health system. Again, the trauma network leaders in all settings should consider an acceptable rate of over-triage, in order to reduce under-triage.

Under-triage in this study was high overall. The under-triaged group were more likely to be over 65 years old (52.3%) than the rest of the study sample (45%), again highlighting the difficulty in accurately triaging older patients. Under-triage impacts on patients and their subsequent morbidity and mortality. It is possible that the performance of trauma networks, measured in unexpected survivors, may improve if under-triage was reduced.

In terms of TUB tool physiological variables, respiratory rate and blood pressure had no significant correlation with ISS>15. However, increasing the BP threshold to <100mmHg for the over-65 population may improve performance of the tool in this age group. Also, consideration should be given to replacing the BP variable with shock index, an easily calculated composite of heart rate and blood pressure. In isolation, the addition of heart rate to the TUB tool had no validity. Only the motor component of GCS had a demonstrable relationship with ISS, however, altering the GCS variable to less than 14 may improve sensitivity and specificity.

The alternative triage scores did not show an improvement in performance over the TUB tool when tested against the same data set. At the time of writing, a study is underway in the same setting, with results due soon, to evaluate the utility of mechanism of injury in predicting IS>15. This may influence further work on refining the TUB tool.

It has been identified in this study and others, that ISS>15 may not be the most useful outcome in terms of identifying patients who would benefit from care in a Major Trauma Centre. The importance of improving the outcome definition, and designing an accurate tool to identify these patients, has been validated by the NIHR funded MATTS study.

Whilst paramedic and pre-hospital clinical decision making was briefly discussed in this study, it should be considered during any further work on triage tool evaluation and development. The existing tool was brought into use when the trauma network was first implemented, to support new ways of working. It may be possible that, ten years later, with a mature system, that the needs of pre-hospital clinicians for this type of decision support is different. This group of clinicians should be involved in any changes to practice in this environment.

The TUB tool was developed, using consensus methods, by an expert panel of clinicians in the region and has now been in use in Wessex for a decade. This study is the first full evaluation of the accuracy of this decision support tool. It highlights the need for review of current clinical practice in the triage of major trauma patients. The use of the TUB tool has guided patient destination throughout this time and could be improved to ensure that more patients are triaged correctly.

7.2 Strengths and limitations

Two sources of data were used, to ensure not only TARN eligible patients were included but also those from the ED Symphony system who had more minor injuries or were discharged from the ED. This was a retrospective review of existing data and therefore, the fields provided from TARN and Symphony were the only available variables. The benefit of a prospective review over this would be that the data required could be identified initially and collected in the desired format. In addition, it was not possible to interview the clinicians involved in trauma triage, either in person or via another means such as completion of a questionnaire. This would have allowed a more accurate means of identifying if the clinician felt that the TUB tool was positive or negative for each case, rather than making the assumptions outlined in 3.6. However, data completeness was high, with no cases lost due to missing details. A whole year of data were analysed, to remove any effect from seasonal influences such as weather, hours of daylight, working practices or population of the region.

Anatomical injuries were assigned to cases based on review of the notes, including post-imaging. This of course does not reflect the ability of clinicians in the pre-hospital environment to identify these injuries through physical examination. Many injuries considered in the evaluation may not have been identifiable in the pre-hospital phase. This could be addressed in future work by employing a prospective approach to data collection.

Where pre-hospital observations were missing, these were replaced by values obtained in the emergency department. These were likely to have been obtained following a period of resuscitation and so may not accurately reflect the patient's condition when the EMS crew initially assessed the patient. The quality of the data will be affected by that entered by clinicians managing high acuity patients and the opportunity for error or transposition of figures is present (6.5.1). Since these data were collected, SCAS now has the ability to link the patient monitor with the patient record. This may result in more complete and accurate data.

The scope of this project did not extend to making the recommended changes to the TUB tool and then testing this in clinical practice. Quality improvement methodology, commonly employed in healthcare settings, would recommend several PDSA (plan-do-study-act) cycles following on from service evaluation to implement changes in practice (Taylor et al., 2014).

The work has already been disseminated within the Wessex Trauma Network, resulting in greater awareness of the challenges around trauma triage and the effectiveness of the tool in predicting which patients require transport to the MTC.

7.3 Implications for practice

As part of a professional doctorate, it is important that this work has direct translation to clinical practice and can inform future working. The key finding, that the Wessex TUB tool does not perform well in predicting need for transfer to MTC, has important implications. A key consideration is to identify if the TUB tool is a guideline or a decision rule. The former suggests that it can be used to guide practice, in conjunction with a clinician's skills, knowledge and experience. The latter describes a protocol which must be adhered to, with possible connotations of consequences if it is deviated from. On its inception in 2012, TU bypass was a new concept, that ambulance crews would be expected to transport severely injured patients longer distances, perhaps even driving past the closest ED. There was, quite understandably, apprehension about this change in practice, and concern that patients may die in the back of an ambulance when they could have been in a hospital setting. The TUB tool helped to alleviate some of these concerns as it provided a formal guide that could be utilised and then referred to in such a case. It could be argued that this is a defensive attitude by ambulance clinicians but informal observation in practice raised these concerns. The attitude of ED clinicians is extremely influential in these cases. If the ED staff are willing to accept patients without question, this may make clinicians more comfortable in transporting equivocal cases to an MTC. However, if the decision to transport the patient to an MTC rather than a TU is questioned, the TUB tool may be used either as a defence or to query the ambulance crew's decision-making. This has been observed in practice and reported to the WTN through adverse incident reporting by clinicians. As it is now clear that the tool is not an accurate predictor of severe injury, it is recommended that it is not used as a rule or as a tool to criticise practice. It could be argued that, in 2012 when the WTN was launched, the TUB tool had more application than it does now that Trauma Unit Bypass is accepted and common practice. Where apprehensions may have initially existed, more paramedics will have now trained in a system where this is usual practice. Therefore, the need for a decision support tool around which patients should bypass may no longer be as important as when TU bypass was introduced.

This work contributes to the knowledge, relevant to the local population, around factors which influence under-triage of patients. This should be disseminated to pre-hospital clinicians to assist them in making informed decisions. For example, we can now be cognisant of the fact that patients who are older, or who do not have obvious severe injury, are more likely to be under-triaged. Therefore, clinicians can actively seek to assess 'hidden' injuries and approach older patients with a high index of suspicion for severe injury, particularly in combination with comorbidities or medications which alter physiology.

Any further work to evaluate changes to the TUB tool should be undertaken with caution. There is a risk in changing the tool in that, if the performance deteriorates rather than improves and the tool has to be changed again, that confusion occurs. Version control could become problematic and lead to potential conflict between clinicians. It is therefore recommended that further modelling with a newer data set occurs prior to implementation of a new or additional tools. The current tool was introduced without any pilot phase or validation prior to use, and it has now been found to not perform as well as would be desired. This situation could be avoided in future by prospective modelling of any new decision support tools.

The significance of the research question investigated here is emphasised by the development of a large scale, nationwide project aimed at improving trauma triage tools used in the UK (2.9.2). Whilst this study provides useful insight into the local situation, and results could be extrapolated to the wider English population, it is likely that this new study will supersede any changes made in response to the study presented here. However, it does bring to light the poor performance of the current tool and the limitations of using ISS>15 as an outcome measure.

7.3.1 Recommendations for future work

The recommendations of this report in relation to the Wessex TUB tool are:

7.3.1.1 Modifications to the TUB tool

The TUB tool should be amended in the following ways for use in further evaluation:

- Blood pressure variable is altered to 'systolic BP of <100mmHg'
- GCS variable is altered to GCS <14

- Pelvic fracture component is changed to match that of the SWASFT tool to provide additional support in identifying major trauma
- Consideration is given to an additional section to 'consider medications and co-morbidities including use of anti-coagulants'

These recommendations could form a prospective study, evaluating the new tool, alongside the current TUB tool. This would require either additional data capture, on ambulance service or ED records, or interviewing of crews who transport major trauma patients. Both of these approaches are likely to require significant resource and therefore funding.

It is recommended that, as per 7.3.1.3 below, additional outcome measures are utilised in future research to evaluate need for MTC specialist services rather than solely ISS<15. As described, any increase in sensitivity of the tool is likely to be at the expense of specificity, resulting in an increased demand on MTC resources. The acceptable levels of Sn and Sp must be decided at a system level.

7.3.1.2 Further research

There are six specific areas for future research which have been identified:

1. Investigate combining anatomical and physiological variables (e.g. chest injury with increased respiratory rate or fall in oxygen saturations). This may improve the recognition of significant injuries such as flail chest, major pelvic fracture and head injury requiring neurosurgical input.

2. Evaluation of adding 'penetrating thorax injury' to the anatomical section. Whilst pre-hospital clinicians would generally appreciate the time critical nature of an injury caused by stabbing, it does not currently form part of the TUB tool.

3. Modelling of shock index (in place of blood pressure) and mNFTI in trauma triage. Evidence from other studies suggests that this can improve the performance of pre-hospital triage tool (6.5.5.3) and it can be calculated simply by current software in use for patient records.

   It is suggested that this modelling takes place, either using the existing data set or with newer data, to evaluate these combined variables. If additional,

more recent data is selected, it would be preferable to employ a prospective methodology to improve data accuracy and to collect additional fields.

4. Mechanism of injury as a means of predicting major trauma is investigated in the local population.

   This forms the basis of work currently in progress at UHS and is due to be submitted to a peer-reviewed journal in 2022.

5. Further work is undertaken into how clinicians use the TUB tool. Should a prospective study be conducted, this would provide an opportunity to collect qualitative data from ambulance clinicians around the use of the TUB tool. It would be useful to understand whether the TUB is used in all cases of trauma, or if it is only consulted in equivocal cases or where there may be disagreement between clinicians on scene. It would be interesting to note if a paper or app-based solution is most commonly deployed in practice. An important area to study would be to evaluate the clinician's confidence in the current tool and how much they value it as a decision-support tool.

6. Patients are evaluated with regards interventions carried out whilst in hospital, for example a patient who was not TUB positive but received surgery only available at an MTC. This analysis could help inform the need for Major Trauma Centre specialist services, for example cardiothoracic surgery or neurosurgery.

7.3.1.3 System-level work

There are two primary issues for trauma networks to consider at a system level:

1. The desired outcome for trauma triage (need for MTC rather than ISS>15). Whilst objective measures such as ICU admission and need for emergency operation can be evaluated, there are also some less tangible services offered by MTCs such as senior team leadership by an experienced consultant. The Wessex Trauma Network should decide if the purpose of the TUB tool is to triage patients who need specialist services or to identify patients who will be TARN eligible with an ISS>15.

2. An education package is developed for pre-hospital clinicians around patients who are commonly under-triaged (i.e. the elderly, those without

pelvis or long bone injuries, those with a higher GCS). This could help the recognition of injuries and improve trauma triage.

Some of the recommendations for further research are likely to be superseded by the MATTS team as part of their NIHR funded study. This is likely to produce recommendations for a national triage tool and it is likely that this will be adopted by all Trauma Networks including Wessex. It will be interesting to understand the performance of this tool which will need to be utilised across both urban and rural populations. However, this is attractive in simplifying systems to a unified tool, especially in ambulance trusts which service a number of trauma networks (for example South East Coast Ambulance Service which transports patients to London, Wessex and Kent, Surrey and Sussex hospitals).

7.3.2 Dissemination

This work has been presented at the Wessex Trauma Network Annual Conference (2019), the WTN Trauma breakfast meeting (2021) and the UHS Emergency Department clinical governance meeting (2021). Invitations have also been received to speak at educational conferences and local clinical governance meetings.

The intention is that following submission of this thesis, papers are prepared for submission to peer-reviewed journals.

As outlined above (7.3.1.2), further work is being carried out to evaluate MOI in predicting ISS>15 and will be prepared for publication. Future outputs are likely to include:

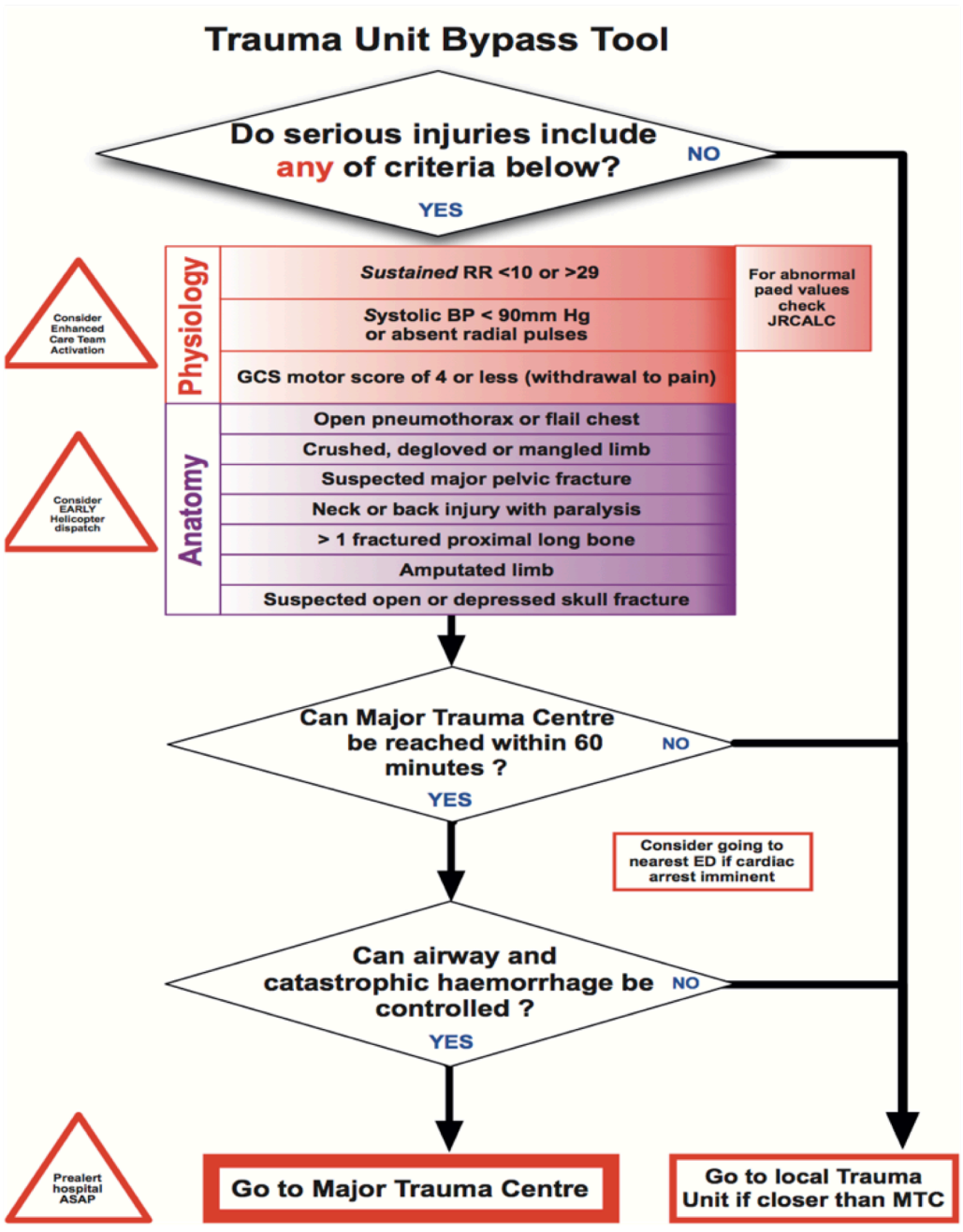
- An evaluation of the Trauma Unit Bypass tool in predicting major trauma
- The utility of mechanism of injury in major trauma triage
- Recommendations for modifications to major trauma triage to improve the identification of severely injured patients
- Characteristics of patients under-triaged in major trauma

In summary, this doctoral study was a retrospective review of data from the Wessex Trauma Network which included patients suspected of having sustained

major trauma, over a one-year period. The accuracy of the TUB tool in predicting ISS>15 was evaluated, demonstrating that the triage tool did not perform well. Further analysis was carried out to understand which TUB tool criteria were effective, and modifications to the tool modelled with the same data set. Recommendations for changes in clinical practice and for future work have been made, along with the means for dissemination of this work. This work contributes to clinical practice by not only highlighting modifications that can be made to improve the performance of a triage tool, but also demonstrating the difficulties with the current measure of major trauma used internationally.

Appendix A Wessex Trauma Network Trauma Unit Bypass Tool

South Central Ambulance Service NHS
NHS Foundation Trust



Appendix B Patient information

Improving major trauma triage

Clinicians in Southampton are evaluating a tool used by ambulance crews to decide on the most appropriate hospital destination for patients involved in traumatic incidents.

The tool, which was introduced in 2012 in line with the Wessex Trauma Network (WTN), categorises all hospitals in the Wessex region into trauma units, local emergency hospitals and the major trauma centre, depending on their services, and also includes all ambulance services in the region.

Used as an electronic app or a printed flow diagram, the service assists paramedics to triage emergency patients and determine the most suitable WTN hospital for treatment.

Created to improve care for patients with severe injuries, the WTN ensures that the most severely injured patients can be managed in a centre equipped to provide all of the required specialist services. Southampton General Hospital is the major trauma centre for the region, accepting patients from across the area, even if there is a closer emergency department.

Improving accuracy

Now, six years later, clinical-academics are reviewing the system's capabilities in order to make improvements to the service.

Els Freshwater, consultant paramedic at University Hospital Southampton NHS Foundation Trust, is leading the evaluation of the tool to understand how it can be improved and developed further.

It is hoped that improvements will increase better on-the-spot assessments and allow paramedics and teams to make more informed decisions based on each patient's specific needs. Better accuracy will also reduce the need for transfers between units after patients have been admitted, which will in turn save resources and improve patient care.

Freshwater plans to use data collected from 1 October 2016 to 30 September 2017. Information will be obtained from Southampton General Hospital's emergency department records and Trauma Audit Research Network data and will be used to identify;

- the location of each incident
- the type of injuries
- the vital signs at the scene.

Opting out

If you were taken by ambulance or air ambulance to Southampton General Hospital with traumatic injuries between 1 October 2016 and 30 September 2017, anonymised data from your health records may be used in the analysis in this study.

If you would prefer for your data not to be used in this study, please email els.freshwater@uhs.nhs.uk

http://www.uhs.nhs.uk/ClinicalResearchinSouthampton/Research/News-and-updates/Articles/Improving-major-trauma-triage.aspx

https://www.aftertrauma.org/forum/viewtopic.php?f=1&t=48&p=86&hilit=freshwater&sid=114409a49c7e5b06cf98551f1ee782c3#p86

Appendix C Data collection proforma

Characteristics of under- and over-triaged incidents

Record number		
Patient age		
Gender		
Mode of transport to ED	Ambulance	
	Helicopter	
	Personal	
Postcode of incident		
Type of incident	RTC	
	Fall	
	Blast	
	Sport	
	Assault	
	Self harm	
	Fire	
	Other	
Time from injury to EMS arrival (mins)		
Pre-hospital physiology	Heart rate	
	Respiratory rate	
	Systolic BP	
	Diastolic BP	
	SPO2	
	GCS - E	
	GCS - V	
	GCS - M	
	Blood sugar	
	ETCO2	
Areas of injury	Head	
	Spine	
	Chest	
	Abdomen	
	Pelvis	
	Limbs	

Highest level crew on scene	Technician	☐
	Nurse	☐
	Paramedic	☐
	Specialist Paramedic	☐
	Doctor	☐

Pre-hospital interventions	Surgical airway	☐
	RSI	☐
	Intubation - no drugs	☐
	SGA	☐
	Other airway	☐
	Intraosseous access	☐
	Immobilisation	☐
	Chest decompression	☐
	IO access	☐
	Pelvic binder	☐
	Femoral traction	☐
	Extremity splint	☐
	Procedural sedation	☐

Notes

Appendix D Letter of HRA approval

Health Research Authority

Ms Eleanor Freshwater
Advanced Clinical Practitioner
University Hospitals Southampton
Tremona Road
Southampton
Hampshire
SO16 6YD

Email: hra.approval@nhs.net

21 December 2017

Dear Ms Freshwater

Letter of HRA Approval

Study title:	**Evaluation of the sensitivity and specificity of the Wessex Trauma Network trauma unit bypass tool in predicting major trauma, with suggestions for modifications to assist pre-hospital clinicians in appropriate triage and transport.**
IRAS project ID:	**219069**
Protocol number:	**n/a**
REC reference:	**17/SC/0511**
Sponsor	**University Hospital Southampton**

I am pleased to confirm that **HRA Approval** has been given for the above referenced study, on the basis described in the application form, protocol, supporting documentation and any clarifications noted in this letter.

Participation of NHS Organisations in England

The sponsor should now provide a copy of this letter to all participating NHS organisations in England.

Appendix B provides important information for sponsors and participating NHS organisations in England for arranging and confirming capacity and capability. **Please read *Appendix B* carefully**, in particular the following sections:

- *Participating NHS organisations in England* – this clarifies the types of participating organisations in the study and whether or not all organisations will be undertaking the same activities
- *Confirmation of capacity and capability* - this confirms whether or not each type of participating NHS organisation in England is expected to give formal confirmation of capacity and capability. Where formal confirmation is not expected, the section also provides details on the time limit given to participating organisations to opt out of the study, or request additional time, before their participation is assumed.
- *Allocation of responsibilities and rights are agreed and documented (4.1 of HRA assessment criteria)* - this provides detail on the form of agreement to be used in the study to confirm capacity and capability, where applicable.

IRAS project ID	219069

Further information on funding, HR processes, and compliance with HRA criteria and standards is also provided.

It is critical that you involve both the research management function (e.g. R&D office) supporting each organisation and the local research team (where there is one) in setting up your study. Contact details and further information about working with the research management function for each organisation can be accessed from the HRA website.

Appendices

The HRA Approval letter contains the following appendices:

- A – List of documents reviewed during HRA assessment
- B – Summary of HRA assessment

After HRA Approval

The document *"After Ethical Review – guidance for sponsors and investigators",* issued with your REC favourable opinion, gives detailed guidance on reporting expectations for studies, including:

- Registration of research
- Notifying amendments
- Notifying the end of the study

The HRA website also provides guidance on these topics, and is updated in the light of changes in reporting expectations or procedures.

In addition to the guidance in the above, please note the following:

- HRA Approval applies for the duration of your REC favourable opinion, unless otherwise notified in writing by the HRA.
- Substantial amendments should be submitted directly to the Research Ethics Committee, as detailed in the *After Ethical Review* document. Non-substantial amendments should be submitted for review by the HRA using the form provided on the HRA website, and emailed to hra.amendments@nhs.net.
- The HRA will categorise amendments (substantial and non-substantial) and issue confirmation of continued HRA Approval. Further details can be found on the HRA website.

Scope

HRA Approval provides an approval for research involving patients or staff in NHS organisations in England.

If your study involves NHS organisations in other countries in the UK, please contact the relevant national coordinating functions for support and advice. Further information can be found through IRAS.

If there are participating non-NHS organisations, local agreement should be obtained in accordance with the procedures of the local participating non-NHS organisation.

IRAS project ID	219069

User Feedback

The Health Research Authority is continually striving to provide a high quality service to all applicants and sponsors. You are invited to give your view of the service you have received and the application procedure. If you wish to make your views known please use the feedback form available on the HRA website.

HRA Training

We are pleased to welcome researchers and research management staff at our training days – see details on the HRA website.

Your IRAS project ID is **219069**. Please quote this on all correspondence.

Yours sincerely

Catherine Adams
Senior Assessor
Email: hra.approval@nhs.net

Copy to: *Ms Emily Watkins, Sponsor's Representative*
Sharon Davies-Dear, University Hospital Southampton NHS Foundation Trust

IRAS project ID	219069

Appendix A - List of Documents

The final document set assessed and approved by HRA Approval is listed below.

Document	*Version*	*Date*
Confirmation of any other Regulatory Approvals (e.g. CAG) and all correspondence	1	20 December 2017
IRAS Application Form [IRAS_Form_08092017]		08 September 2017
Letter from funder [Letter from funder]	1	03 March 2017
Referee's report or other scientific critique report [NHS Peer Review]	1	04 August 2017
Referee's report or other scientific critique report [University Peer Reviews]	1	02 March 2017
Research protocol or project proposal [Research Protocol]	3.1	28 August 2017
Summary CV for Chief Investigator (CI) [Chief Investigator CV]	1	18 May 2017
Summary CV for supervisor (student research) [J Turnbull CV]	1	04 August 2017
Summary CV for supervisor (student research) [P White CV]	1	31 July 2017

IRAS project ID	219069

Appendix B - Summary of HRA Assessment

This appendix provides assurance to you, the sponsor and the NHS in England that the study, as reviewed for HRA Approval, is compliant with relevant standards. It also provides information and clarification, where appropriate, to participating NHS organisations in England to assist in assessing and arranging capacity and capability.

For information on how the sponsor should be working with participating NHS organisations in England, please refer to the, *participating NHS organisations, capacity and capability* and *Allocation of responsibilities and rights are agreed and documented (4.1 of HRA assessment criteria)* sections in this appendix.

The following person is the sponsor contact for the purpose of addressing participating organisation questions relating to the study:

Ms Emily Watkins
E-mail emily.watkins@uhs.nhs.uk

HRA assessment criteria

Section	HRA Assessment Criteria	Compliant with Standards	Comments
1.1	IRAS application completed correctly	Yes	No comments
2.1	Participant information/consent documents and consent process	n/a	
3.1	Protocol assessment	Yes	No comments
4.1	Allocation of responsibilities and rights are agreed and documented	Yes	This is a single site study where the Sponsor is the same organisation. No agreement is required.
4.2	Insurance/indemnity arrangements assessed	Yes	Where applicable, independent contractors (e.g. General Practitioners) should ensure that the professional indemnity provided by their medical defence organisation covers the activities expected of them for this research study
4.3	Financial arrangements assessed	Yes	No comments

IRAS project ID	219069

Section	HRA Assessment Criteria	Compliant with Standards	Comments
5.1	Compliance with the Data Protection Act and data security issues assessed	Yes	No comments
5.2	CTIMPS – Arrangements for compliance with the Clinical Trials Regulations assessed	Yes Not Applicable	No comments
5.3	Compliance with any applicable laws or regulations	Yes	CAG approval received
6.1	NHS Research Ethics Committee favourable opinion received for applicable studies	Yes	No comments
6.2	CTIMPS – Clinical Trials Authorisation (CTA) letter received	Not Applicable	No comments
6.3	Devices – MHRA notice of no objection received	Not Applicable	No comments
6.4	Other regulatory approvals and authorisations received	Not Applicable	No comments

Participating NHS Organisations in England

This provides detail on the types of participating NHS organisations in the study and a statement as to whether the activities at all organisations are the same or different.
This is a single site study therefor there is only one 'site-type'. If this study is subsequently extended to other NHS organisation(s) in England, an amendment should be submitted to the HRA, with a Statement of Activities and Schedule of Events for the newly participating NHS organisation(s) in England. If chief investigators, sponsors or principal investigators are asked to complete site level forms for participating NHS organisations in England which are not provided in IRAS or on the HRA website, the chief investigator, sponsor or principal investigator should notify the HRA immediately at hra.approval@nhs.net. The HRA will work with these organisations to achieve a consistent approach to information provision.

IRAS project ID	219069

Confirmation of Capacity and Capability

This describes whether formal confirmation of capacity and capability is expected from participating NHS organisations in England.
This is a single site study sponsored by the site. The R&D office will confirm to the CI when the study can start.

Principal Investigator Suitability

This confirms whether the sponsor position on whether a PI, LC or neither should be in place is correct for each type of participating NHS organisation in England and the minimum expectations for education, training and experience that PIs should meet (where applicable).
A Principal Investigator is expected at the participating organisation. GCP training is not a generic training expectation, in line with the HRA/MHRA statement on training expectations.

HR Good Practice Resource Pack Expectations

This confirms the HR Good Practice Resource Pack expectations for the study and the pre-engagement checks that should and should not be undertaken
No Honorary Research Contracts, Letters of Access or pre-engagement checks are expected for local staff employed by the participating NHS organisations. Where arrangements are not already in place, research staff not employed by the NHS host organisation undertaking any of the research activities listed in the research application would be expected to obtain a Letter of Access. No pre-engagement checks are required.

Other Information to Aid Study Set-up

This details any other information that may be helpful to sponsors and participating NHS organisations in England to aid study set-up.
The applicant has indicated that they do not intend to apply for inclusion on the NIHR CRN Portfolio.

South Central - Hampshire A Research Ethics Committee
Level 3, Block B
Whitefriars
Lewins Mead
Bristol
BS1 2NT

Telephone: 0207 104 8049

Please note: This is the favourable opinion of the REC only and does not allow you to start your study at NHS sites in England until you receive HRA Approval

19 October 2017

Ms Eleanor Freshwater
Advanced Clinical Practitioner
University Hospitals Southampton
Tremona Road
Southampton
Hampshire
SO16 6YD

Dear Ms Freshwater

Study title:	**Evaluation of the sensitivity and specificity of the Wessex Trauma Network trauma unit bypass tool in predicting major trauma, with suggestions for modifications to assist pre-hospital clinicians in appropriate triage and transport.**
REC reference:	**17/SC/0511**
Protocol number:	**n/a**
IRAS project ID:	**219069**

The Research Ethics Committee reviewed the above application at the meeting held on 10 October 2017. Thank you for attending to discuss the application.

We plan to publish your research summary wording for the above study on the HRA website, together with your contact details. Publication will be no earlier than three months from the

date of this favourable opinion letter. The expectation is that this information will be published for all studies that receive an ethical opinion but should you wish to provide a substitute contact point, wish to make a request to defer, or require further information, please contact hra.studyregistration@nhs.net outlining the reasons for your request. Under very limited circumstances (e.g. for student research which has received an unfavourable opinion), it may be possible to grant an exemption to the publication of the study.

Ethical opinion

The members of the Committee present gave a favourable ethical opinion of the above research on the basis described in the application form, protocol and supporting documentation, subject to the conditions specified below. .

Conditions of the favourable opinion

Management permission must be obtained from each host organisation prior to the start of the study at the site concerned.

Management permission should be sought from all NHS organisations involved in the study in accordance with NHS research governance arrangements. Each NHS organisation must confirm through the signing of agreements and/or other documents that it has given permission for the research to proceed (except where explicitly specified otherwise).

Guidance on applying for HRA Approval (England)/ NHS permission for research is available in the Integrated Research Application System, at www.hra.nhs.uk or at http://www.rdforum.nhs.uk.

Where a NHS organisation's role in the study is limited to identifying and referring potential participants to research sites ("participant identification centre"), guidance should be sought from the R&D office on the information it requires to give permission for this activity.

For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.

Sponsors are not required to notify the Committee of management permissions from host organisations.

Registration of Clinical Trials

All clinical trials (defined as the first four categories on the IRAS filter page) must be registered on a publically accessible database. This should be before the first participant is recruited but no later than 6 weeks after recruitment of the first participant.

There is no requirement to separately notify the REC but you should do so at the earliest opportunity e.g. when submitting an amendment. We will audit the registration details as part of the annual progress reporting process.

To ensure transparency in research, we strongly recommend that all research is registered but for non-clinical trials this is not currently mandatory.

If a sponsor wishes to request a deferral for study registration within the required timeframe, they should contact hra.studyregistration@nhs.net. The expectation is that all clinical trials

will be registered, however, in exceptional circumstances non registration may be permissible with prior agreement from the HRA. Guidance on where to register is provided on the HRA website.

It is the responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

Ethical review of research sites

NHS Sites

The favourable opinion applies to all NHS sites taking part in the study taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" below).

Summary of discussion at the meeting

Social or scientific value; scientific design and conduct of the study

The Committee asked for an overview of the research project.

You explained that for the past five years major trauma networks have used a trauma unit bypass tool to triage patients either to a major trauma centre with specialist services or to a local hospital unit. Previously, trauma patients would have been taken to their nearest Accident & Emergency department. Anecdotal feedback has suggested that the tool could be improved such that patients can be managed appropriately closer to home where possible. Based on this, the research team aimed to evaluate the tool's sensitivity and specificity in the first phase of the project, and then to refine it if necessary. She explained that one tool is currently used for patients of all ages, despite paediatric patients responding differently to traumatic injuries, and despite there being concern that trauma is currently under identified amongst elderly patients. The second phase of the research would therefore propose alterations to the tool and evaluate them using the data, with the aim of getting patients to the best hospital for their needs as quickly as possible.

The Committee accepted this response, and added that this would be a valuable research project.

Care and protection of research participants; respect for potential and enrolled participants' welfare and dignity

The Committee asked whether it would be likely that the research team would come across instances of poor practice.

You explained that there are systems in place for reviewing trauma cases through both regional and local morbidity and mortality meetings, and that working with the Trauma Audit Research Network (TARN) allows open dialogue for people to discuss and raise complaints. You acknowledged that the data might reveal surprising things, but pointed out that as an external researcher trying to understand how the tool is used these would be an opportunity to learn. You noted that it would be unlikely that anything not already identified by another agency would be identified.

The Committee asked what would happen if something was identified.

You explained this would be raised via the network governance route, and that all data would already have been reviewed and evaluated by TARN.

The Committee accepted this response.

Other general comments

The Committee noted that an application had been made to the Confidentiality Advisory Group (CAG), and asked whether a decision had been issued for this yet.

You informed the Committee that the CAG review was scheduled for Thursday 12 October 2017.

The Committee accepted this response.

Other ethical issues were raised and resolved in preliminary discussion before your attendance at the meeting.

Please contact the REC Manager if you feel that the above summary is not an accurate reflection of the discussion at the meeting.

Approved documents

The documents reviewed and approved at the meeting were:

Document	*Version*	*Date*
IRAS Application Form [IRAS_Form_08092017]		08 September 2017
Letter from funder [Letter from funder]	1	03 March 2017
Referee's report or other scientific critique report [NHS Peer Review]	1	04 August 2017
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Summary CV for supervisor (student research) [J Turnbull CV]	1	04 August 2017
Summary CV for supervisor (student research) [P White CV]	1	31 July 2017

Membership of the Committee

The members of the Ethics Committee who were present at the meeting are listed on the attached sheet.

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Reporting requirements

The attached document “After ethical review – guidance for researchers” gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Notification of serious breaches of the protocol
- Progress and safety reports
- Notifying the end of the study

The HRA website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

User Feedback

The Health Research Authority is continually striving to provide a high quality service to all applicants and sponsors. You are invited to give your view of the service you have received and the application procedure. If you wish to make your views known please use the feedback form available on the HRA website: http://www.hra.nhs.uk/about-the-hra/governance/quality-assurance/

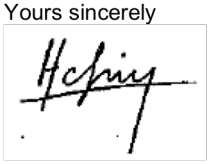
HRA Training

We are pleased to welcome researchers and R&D staff at our training days – see details at http://www.hra.nhs.uk/hra-training/

17/SC/0511	**Please quote this number on all correspondence**

With the Committee’s best wishes for the success of this project.

Yours sincerely



pp. Ms Helen Sivey
REC Manager

Dr Simon Kolstoe
Chair

E-mail: nrescommittee.southcentral-hampshirea@nhs.net

South Central - Hampshire A Research Ethics Committee

Attendance at Committee meeting on 10 October 2017

Committee Members:

Name	*Profession*	*Present*	*Notes*
Dr Jill Adams	GP	Yes	
Mr Richard Andoh	Pharmacist	No	
Mrs Lisa Frances Armstrong	Senior Lecturer Social Work	Yes	
Dr Ronja Bahadori	Clinical Trial Coordinator	Yes	
Ms Sonia Baryschpolec	Staff nurse	Yes	
Dr James Gavin	Academic (Exercise Physiology)	Yes	
Mrs Kathryn Gillanders	Retired Head of Clinical Research	No	
Dr Simon Kolstoe (Chair and Meeting Chair)	Senior Lecturer in Biochemistry	Yes	
Mr Trevor Olding	Clinical Coordinator	Yes	
Dr Emmanouil Papavasileiou	Research Fellow in International Labour Mobility	No	
Ms Amy Peters	REC Assistant	No	
Dr Ramya Ramanujachar	Paediatric Oncology Consultant	No	
Ms Helen Ryan	Head of Law	Yes	
Mrs Margaret Stephens	Senior Specialist, Speech & Language Therapist (Adult Neurology & Elderly Care)	No	
Dr Anja Timm	Senior Research Fellow in Medical Education	Yes	

Also in attendance:

Name	*Position (or reason for attending)*
Mrs Cathy Chesham	Deputy Regional Manager (HRA Observer)
Mr Anthony Homer	Clinical Research Support Worker (Observer)
Ms Helen Sivey	REC Manager
Ms Nicole Tipler	Clinical Trial Administrator (Observer)

Appendix E University of Southampton ERGO approval

From: Ergo <ergo@soton.ac.uk>

Subject: Research Governance Feedback on your Ethics Submission (Ethics ID:24610)

Date: 21 December 2017 at 10:51:57 GMT

To: Freshwater E.S. <esf1c12@soton.ac.uk>

Submission Number 24610:

Submission Title Evaluation of the sensitivity and specificity of the Wessex Trauma Network trauma unit bypass tool in predicting major trauma,with suggestions for modifications to assist pre-hospital clinicians in appropriate triage and transport.:

The Research Governance Office has reviewed and approved your submission

You can begin your research unless you are still awaiting specific Health and Safety approval (e.g. for a Genetic or Biological Materials Risk Assessment) or external ethics review (e.g. NRES).The following comments have been made:

"

Submission ID : 24610
Submission Name: Evaluation of the sensitivity and specificity of the Wessex Trauma Network trauma unit bypass tool in predicting major trauma,with suggestions for modifications to assist pre-hospital clinicians in appropriate triage and transport.
Date : 21 Dec 2017
Created by : Eleanor Freshwater

"

Coordinator: Eleanor Freshwater

ERGO : Ethics and Research Governance Online

http://www.ergo.soton.ac.uk

DO NOT REPLY TO THIS EMAIL

#

Appendix F University Hospital Southampton research approval

From: "Marshall, Shauna" <Shauna.Marshall@uhs.nhs.uk>

Subject: 219069 - Confirmation of capacity & capability for University Hospital Southampton NHS Foundation Trust

Date: 22 December 2017 at 08:37:44 GMT

To: "Freshwater, Els" <Els.Freshwater@uhs.nhs.uk>

Cc: Els Freshwater <elsfreshwater@icloud.com>, "Jussila-knappett, Taru" <Taru.Jussila-knappett@uhs.nhs.uk>

Dear Ms. Freshwater

R&D Reference: RHM MED1459

REC No: 17/SC/0511

IRAS Project ID: 219069

Short Study Title: Sensitivity and specificity of the Wessex Trauma Network Bypass Tool

Confirmation of Capacity and Capability

Thank you for submitting the above study to the R&D department. We can confirm that the Trust has the capacity and capability to deliver the above referenced study.

This study must be conducted in line with the research protocol (as approved by REC) at all times, and includes compliance of the following:

1. You understand your roles and responsibilities as the principal investigator upon inspection.
2. You ensure both you and the research team undertake refresher Good Clinical Practice (GCP) training on a regular basis.
3. You ensure any amendments made to the study are submitted to the Research & Development Department for acknowledgment prior to implementation.
4. You report as any serious adverse events / SUSAR to the Research & Development Department and sponsor as detailed in the protocol.
5. You report any adverse incidents on the Trust incident E-reporting system.
6. You participate in regular monitoring visits by the sponsor and/ or R&D staff throughout the duration of the study.
7. You ensure that R&D gets notified when the site is closed or of the study closure.

Please find attached list of documents received for used at site.

If you have any questions relating to this email or required further help whilst undertaking your study, please do not hesitate to contact the R&D Department and we will be happy to help you. The R&D Department look forward to working with you.

Many Thanks

Yours Sincerely,

Shauna

Shauna Marshall

Divisional Research Manager (Division B)

Appendix F

R&D Department

University Hospital Southampton NHS Foundation Trust

SGH - Level E, Laboratory & Pathology Block, SCBR, LE123 - MP 138

Southampton

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Tel: +44 (0)23 8120 4901

shauna.marshall@uhs.nhs.uk

Please visit our website at **www.uhs.nhs.uk**

Appendix G Interim Assessment Feedback

UNIVERSITY OF Southampton

Faculty of Environmental and Life Sci

DClinP Interim Assessment

Form: DClinP Interim Assessment Viva

Student Name:	Freshwater, Eleanor Sarah	
Student ID Number:	25837761	
Commence Date:	01 October 2012	
Faculty:	Environmental and Life Sci	
Academic Unit:	School of Health Sciences	
Research Group:	Innovative and Essential Care Research Group	
Degree:	Doctor of Clinical Practice PT (3986)	
Primary Main Supervisor (50%)	Dr JC Turnbull	Innovative and Essential Care Research Group
Second/Co Supervisor (50%)	Dr CD Mclean	Innovative and Essential Care Research Group

Instructions:
You have been approved as an independent Assessor for this student's DClinP Interim Assessment Viva panel. (The panel consists of at least two independent Assessors).
Please review their thesis and following the viva complete the outcome/recommendation form below.
To review the thesis, please click on the tab called 'Upload Mini Thesis', then look at the table of attachments and double click on the report uploaded. Please ensure that your internet browser's pop-up blocker is disabled.
Details about the viva date and who you are assessing with are available by clicking on the tab called 'Nominate Assessors'.
If the recommendation is NOT to pass the student please advise on further action required in the form below.
Once complete please submit for review.
(PGR Tracker user guidance: The first person to write and submit the report becomes the first assessor, permitting the second assessor to sign-off or reject it for further comment. If the second assessor wishes to amend or add to the form, they can click the 'Reject' button and the form will be sent back to both reviewers (as a new task), where either assessor can amend and submit it. It will then progress to the remaining reviewer to submit/sign-off).

For guidance on the criteria for upgrade/interim assessment, please refer to point 68-71 of the Code of Practice for Research Candidature at http://www.calendar.soton.ac.uk/sectionV/code-practice.htmland point 3 of the DClinP Programme regulations at http://www.calendar.soton.ac.uk/sectionX/phd-clinpract.html

Recommendation

Re-submit report only - viva not required

Specify Date

02-Jan-2019

Comments on Viva and Interim Assessment Report by Assessors:

General:
. Interesting topic with clear clinical and service importance
. The full project is a substantial piece of work that has the potential to achieve doctoral standard
. A substantial component of the work has already been completed, but the written document does not clearly convey either the rationale for approach taken or the challenges that were overcome in obtaining the study dataset

. The relationship between the literature and policy/practice and the aims/research questions is not clear
.The document is currently somewhat confusing, especially in Chapter 3, where methods and design of the completed work is hard to distinguish from the plans for the remaining work
. The timescale for completion, the work that needs to be completed and the feasibility of the plans need to be presented in more detail

Specific questions emerging for each chapter are as follows:

Chapter 1: Introduction
. Ensure that the introduction explains the rationale for your study and summarises both a statement of the problem (misidentification of trauma) and service implications, linking these to the over-arching aims of the study. It is useful to indicate both what the study will address and what is beyond the scope of this study.
. Consistent terminology needs to be used throughout and you need clear explanations of service and clinical terms for the non-expert reader. (a glossary would help, but clarity is particularly important in this opening chapter)
. You mention the need for assessment of accuracy of the TUB tool, but also that there is scope to use modelling to improve the tool. Be clear about which of these you are addressing in your study and why. You mention over- and under-triage – in this case, would sensitivity or specificity be more important, given there is a trade-off between the two? This is something that will need to be addressed in the discussion.
. The mechanism of injury component has been removed from the severity of injury tool. Why is this? What are the implications? Have you considered adding this back at the modelling phase?

Chapter 2: Literature review
. Ensure that the introduction to this chapter is clear about what search question(s) were addressed and the reasons – why did you do the review? What information did you hope to get out of it? How did this influence the design and development of your study?
. In table 2, what were the ages, populations, conditions, etc. that were excluded? Why? Did your data collection also exclude these groups? If not, why were they excluded from the review? Again, can this be explored further through the modelling?
. Given what you have said about strengths and weaknesses of the literature, what did you conclude about the implications for your study?
. You need to end this chapter with a clear statement of gaps in the evidence that are being addressed by this study
. Did you use an appraisal tool? Consider using QUADAS, which is suited to diagnostic accuracy studies.

Chapter 3: Methods
. At the start of this chapter, you need a clear statement about your over-arching aim, objectives and research questions
. You note the pros and cons of a prospective study, but what are the pros and cons of your retrospective design? There are many benefits to your design, but these don't emerge in the text.
. You need a clear explanation of your sampling strategy and how this enabled you to answer your research questions.
. The ISS score cut-off for major trauma – you should link this to the NAO review and to your own rationale/aims.
. Make it clear that the ISS is the reference standard and why you chose this.

Chapter 4: Findings
. It isn't clear how your findings on sensitivity/specificity compare to the guidelines you have cited. Does the tool perform well on specificity? By what criteria?
. The discussion of your final thesis will have to address the findings in relation to your questions, the literature and the clinical/service context.

Please list any problems which came to light during the viva and if so, describe what action will be undertaken to overcome them:

. The rationale could be clearer throughout and the relationship between the aims/questions and the choice of design and methods needs to be made explicit through every chapter of the final thesis.
. The critical appraisal of existing evidence is rather superficial and a more sophisticated synthesis will be required for the final thesis – this will include consideration of the quality and quantity of evidence, but also its transferability to the UK/Wessex context.
. The information on remaining work is rather vague and, spread across the introduction and chapters 3/4, it is also confusing. It is difficult to judge the feasibility of the proposed plans for completion.
. You need to consider, how long you have to complete, the size of the thesis required, how much time is needed for

each component and what the proposed work adds in terms of meeting your study objectives.

What action (if any) should be taken by the student with respect to the eventual submission?

For the final thesis, you should work with your supervisors to ensure that the above feedback has been addressed.

For the interim assessment, we would like you to revise the document by adding a short (maximum 3 pages) chapter on the remaining work. We suggest that, where possible, you remove the text relating to completion of the project from earlier sections and put this information in this final chapter (you will probably need a sentence in the introduction chapter about what is being presented in this document and where).

The chapter on project completion should provide a more detailed plan for the remaining analysis (or a protocol for the analysis). The timelines for achieving this should be agreed with your supervisor. We would also like to see a short section on dissemination plans, which can then be expanded on for the final thesis.

Please use track changes to show where material has been revised or new material added.

We have given you a deadline of the 2nd of January 2019. We don't anticipate this work will take that long, but this allows for the Christmas period.

BW 12/03/19 the additional document requested has been reviewed. it is clear from this document that you have taken statistical advice and have a plan for completion of the work. The only additional comment in relation to this is that it would be advisable to discuss data collection and selection of variables (for the case note review) with your supervisors to ensure that the approach is systematic. This process needs to be described clearly in the thesis.

Do you feel that this student will ultimately achieve the award? If not, why not?

Yes, this work clearly has the potential to reach the required standard with revisions as proposed in the feedback.

Electronic Signatures (automatically added when form is submitted)

Wait for DClinP Interim Assessment

Signed:	Ms E FRESHWATER	22 Oct 2018 14:55

Upload Mini Thesis

Signed:	Ms E FRESHWATER	22 Oct 2018 14:58

Nominate Assessors

Signed:	Dr JC Turnbull	23 Oct 2018 15:46

DGS approves nomination of Assessor

Signed:	Prof BA El Wilid	27 Oct 2018 19:09

DClinP Interim Assessment Viva

Signed:	Dr BM Walsh	12 Apr 2019 09:37

Remaining Assessor Sign Off

Signed:	Dr JMG Jones	23 Apr 2019 12:11

Supervisor Sign Off

Signed:	Dr JC Turnbull	23 Apr 2019 12:32

Student to review Interim Assessment report

Signed:	Ms ES Freshwater	25 Apr 2019 13:35

DGS Review of Interim Assessment

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