Article:

Fuller, G. orcid.org/0000-0001-8532-3500, Pandor, A. orcid.org/0000-0003-2552-5260, Essat, M. orcid.org/0000-0003-2397-402X et al. (6 more authors) (2021) Diagnostic accuracy of prehospital triage tools for identifying major trauma in elderly injured patients: A systematic review. Journal of Trauma and Acute Care Surgery, 90 (2). pp. 403-412. ISSN 2163-0755

https://doi.org/10.1097/ta.0000000000003039

BACKGROUND

Major trauma is an important and life-threatening condition (1). Globally, there are over 5 million deaths each year and considerably more people are temporarily or permanently disabled (2). Management at a Major Trauma Centre (MTC), defined as a specialist hospital capable of resuscitation and definitive care of severely injured patients, with immediate emergency access to consultant-delivered specialist major trauma services and expertise (3), may improve survival and functional outcomes following such injuries (4). In order to benefit from this expert care, ambulance crews use pre-hospital trauma triage tools to help them identify people with suspected major trauma at the scene of injury. Patients may then be transported directly to a MTC, bypassing any closer non-specialist hospitals (non-MTCs), with pre-alerting of the emergency department to allow assembly of a trauma team. However, the presence of serious injury at the scene is not always obvious and pre-hospital assessment can be challenging. Bypassing and pre-alerting of patients with no potential to benefit from MTC care ('over-triage') could waste time, money and resources. It could also inconvenience patients and their families by taking them further from home. In contrast, failing to recognise appropriate patients with serious injury ('under-triage') could result in transport to non-MTC's and lack of trauma team activation and specialist facilities, resulting in less effective treatment and poorer outcomes.

In developed countries, recent demographic changes have had a profound effect on the epidemiology of major trauma, with a 'silver tsunami' of serious injury in the elderly (1, 5). Despite this increasing incidence, current pre-hospital triage systems may fail to identify a large proportion of elders with major trauma, who are subsequently subject to under-triage, increased mortality and poorer recovery (6). Older adults are a particularly vulnerable population and tend to have more cognitive and physical impairments and can incur serious injuries from low energy trauma mechanisms (e.g. ground level falls) (7). In addition, pre-existing medical conditions, frailty and medications (e.g. anticoagulants, antiplatelets) can further complicate traumatic injuries and could interfere with the initial paramedic judgements (8).

Recently published systematic reviews have examined the diagnostic accuracy of pre-hospital triage protocols in selecting severely injured adults and children (9-11). However, a study of existing pre-hospital triage tools specifically for older adults is lacking. The aim of this systematic review is to examine diagnostic performance of pre-hospital triage tools for identification of major trauma in elderly patients presenting to emergency medical services (EMS) following injury.

METHODS

Study design

The study was undertaken in accordance with the general principles recommended by expert consensus guidelines for the conduct of diagnostic accuracy systematic reviews (12, 13) and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (14). A pre-specified review protocol was also registered with the PROSPERO international prospective register of systematic reviews (CRD42020150342).

Eligibility criteria

Prospective or retrospective studies reporting diagnostic accuracy metrics were eligible if they examined any multivariable pre-hospital major trauma triage tool (either evaluated according to actual paramedic decision or scored using observed patient variables) compared with any reference standard for major trauma such as Injury Severity Score (ISS). The study population was elderly adults evaluated in a pre-hospital setting and who required transport by land EMS following injury. The review question and inclusion criteria are detailed in Table 1.

[INSERT TABLE 1]

Although a standard consensus definition of elderly has not been established, a cut-off of over 60 years is commonly used (15). In addition, data from the UK Trauma Audit and Research Network suggest a change in the age and outcome relationship at about 60 years (6). If studies included participants less than 60 years of age, we included the study if it was possible to identify the ratio of participants who were more than 60 years of age; if the ratio was more than 75% we included these studies. In case of studies with mixed populations, e.g. data for adults above and below 60 years of age which could not be separated, the study authors were contacted to provide the data separately for the group of interest, where possible. Studies including people presenting to the emergency department via non-EMS i.e. private transportation or helicopter transport were excluded.

Data sources and searches

Potentially relevant studies were identified through searches of ten electronic databases including MEDLINE (1946 to February 2019), EMBASE (1974 to February 2019), CINAHL (1981 to February 2019) and the Cochrane Library (2019, issue 5). The search strategy used free text and thesaurus terms and combined synonyms relating to the condition (e.g. pre-hospital trauma triage) with risk assessment model terms (used in the searches of MEDLINE, Cochrane Library and EMBASE only). Searches were supplemented by examination of the reference lists of all relevant studies (including existing systematic reviews), performing a citation search of relevant articles, contacting key experts in the field and undertaking systematic keyword searches of the World Wide Web using the Google search engine. No language or date restrictions were used on any database. Further details on the search strategy can be found in Supplemental Digital Content 1, Appendix A.

Study selection

All titles were examined for inclusion by one reviewer (ME) and any citations that clearly did not meet the inclusion criteria (e.g. non-human, unrelated to pre-hospital major trauma triage) were excluded. All abstracts and full text articles were then examined independently by two reviewers (ME and HC or AP and LS). Any disagreements in the selection process were resolved through discussion with a third reviewer (GF) and included by consensus.

Data extraction and risk of bias assessment

Data relating to study design, methodological quality, diagnostic accuracy, and outcomes were extracted by one reviewer (ME or AP) into a standardised data extraction form and independently checked for accuracy by a second (CH, HC or LS). Any discrepancies were resolved through discussion to achieve agreement. Where differences were unresolved, a third reviewer's opinion was sought (GF). Where multiple publications of the same study were identified, data were extracted and reported as a single study. In papers focusing primarily on adult triage, subgroup results relating to elders were extracted. If multiple triage tools were evaluated in elderly patients within a single study, results were extracted separately as distinct index test assessments. Where results were reported for various thresholds of a single triage tool, the version giving results closest to American College of Surgeons Committee on Trauma (ACS-COT) triage guidance for sensitivity (95%) and specificity (65-75%) targets were included (16). In the event of multiple elderly subgroup or sensitivity analyses, the primary results for an each individual triage tool were included.

The methodological quality of each included study was assessed using the Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) tool (17). This instrument evaluates four key domains: patient selection, index test, reference standard, flow and timing. Each domain is assessed in terms of risk of bias and the concern regarding applicability to the review (first three domains only). The sub-domains for each domain include a number of signalling questions to guide the overall judgement about whether a study is at high, low, or an unclear (in the event of insufficient data in the publication to answer the corresponding question) risk of bias. Since there are two types of pre-hospital triage-based studies, the original QUADAS-2 tool was modified to include an index test assessment of both real-life triage tool performance (i.e. evaluated according to actual paramedic decision) and diagnostic accuracy (i.e. theoretical results if triage tools were scored using observed patient variables), where reported.

Data synthesis and analysis

Estimates of sensitivity and specificity are presented as point estimates and 95% confidence intervals for individual pre-hospital major trauma triage tools. Results were recalculated if alternative metrics of diagnostic accuracy were originally reported e.g. under-triage (1-

sensitivity) or over-triage (1-specificity). Estimates of sensitivity and specificity for individual triage tools were compared using Forest plots. Results were grouped according to the type of triage evaluation (theoretical diagnostic accuracy versus real-life performance) and study population (undifferentiated injuries versus head injured). Performance was then compared to the ACS-COT benchmark for the triage of trauma patients. Heterogeneity was assessed subjectively by visual inspection, Cochrane Q test, and the I^2 statistic. We were unable to perform meta-analysis as a result of significant levels of heterogeneity between studies, variable reporting of items and the high risk of participant selection bias. As a result, a pre-specified narrative synthesis approach (12, 18) was undertaken. Analyses were conducted using Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA, USA) and Stata 13.1 (StataCorp, College Station, USA).

The overall quality of evidence across studies, was evaluated using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach for diagnostic tests and strategies (19, 20). The quality of evidence was assessed by evaluating the evidence on each outcome for the following domains: study design and conduct (risk of bias), imprecision of diagnostic accuracy estimates (wide confidence intervals), variability in results, indirectness of evidence, or publication bias. The overall quality of evidence was assessed as high, moderate, low, and very low. These levels imply a gradient of confidence in estimates of a diagnostic test strategy on patient outcomes (19).

RESULTS

Study flow

Figure 1 summarises the process of identifying and selecting relevant literature. Of the 1843 citations identified, 15 studies (7, 8, 21-33) investigating 21 index tests (19 unique triage tools), met the inclusion criteria. The majority of the articles were excluded primarily on the basis of an inappropriate target population (not elderly adults with suspected major trauma and evaluated in a pre-hospital setting and transported by land EMS), intervention not a pre-hospital major trauma triage tool or an unsuitable publication type (i.e. reviews, commentaries or editorials). More specifically, four potentially relevant papers (34-37) were excluded as they included potential publication overlap from a single large study. A full list of excluded studies with reasons for exclusion is available on request.

[INSERT FIGURE 1]

Study and patient characteristics

The design and patient characteristics of the 15 included studies (7, 8, 21-33) are summarised in Table 2. All studies were observational cohort studies (2 prospective (23, 33) and 13 retrospective), (7, 8, 21, 22, 24-32) undertaken in Australia (8), Canada (24), Netherlands (33) and the USA, (7, 21-23, 25-32) and were published between 1996 and 2019. Eleven studies (7, 8, 21-27, 29, 32) investigated triage tool accuracy, three studies (30, 31, 33) determined the performance of the triage system and one study (28) assessed both. The majority of included studies examined non-selected injured patients (11 studies), (7, 8, 21-27, 29, 33) with the remainder investigating narrower populations of motor vehicle accident (3 studies) (30-32) or head injury victims (1 study) (28).

While all studies included adult elderly trauma patients, the definition of elderly or older persons ranged between 55+ and 70+. The proportion of male patients ranged from 31% (22) to 60% (28). In studies that reported the cause of suspected major trauma in the elderly, the most common were blunt injuries caused by motor vehicle accidents and falls. Comorbidities and medication use (e.g. anticoagulants and or antiplatelet therapy) was poorly reported. The percentage of patients with major trauma ranged widely from 3% (32) to 32% (21) depending on definition, study design and type of participating hospitals.

[INSERT TABLE 2]

Risk of bias and applicability assessment

The overall methodological quality of the 15 included studies (7, 8, 21-33) is summarised in Table 3 (further details of review author judgements are provided in Supplemental Digital Content 2, Appendix B). The methodological quality of the included studies was variable, with most studies having unclear or high risk of bias and applicability concerns in at least one item of the QUADAS-2 tool. The main risk of bias limitations were related to patient selection (arising from patient exclusions (21, 22, 28, 30, 31, 33) and incomplete patient enrolment), (23, 27, 29) missing index test or outcome data (7, 8, 21-29, 32) and suboptimal matching of pre-hospital and hospital data (7, 22, 24-27). Moreover, for studies examining real-life transport decisions, (28, 30, 31, 33) inclusion of patients injured closest to a MTC could over-estimate sensitivity results, and under-estimate specificity results, as these patients would always be transported to the MTC regardless of triage tool results or EMS provider judgement. Other systematic errors included possible information bias from index test misclassification secondary to retrospective chart review and overfitting of non-externally validated statistical models. Applicability concerns for the majority of studies were generally related to patient selection (highly selected study populations e.g. triage of patients involved in motor vehicle accidents (30-32) or after head injury (28) only; definitions of elderly not fully matching the review question) (7, 8, 23, 28, 31) and unconventional reference standards (major trauma was defined in some studies as intracerebral haemorrhage,(23, 28) ISS>12 (8), or any Abbreviated Injury Scale score ≥3) (31).

[INSERT TABLE 3]

Diagnostic performance of pre-hospital trauma triage protocols

The diagnostic performance of pre-hospital major trauma triage tools is summarised in Figures 2 and 3, (further details are provided in Supplemental Digital Content 3, Appendix C). All triage tools included an assessment of vital signs, suspicion of certain anatomic injuries, and specific mechanisms of injury.

[INSERT FIGURE 2 AND FIGURE 3]

Triage accuracy fell below ACS-COT suggested triage targets for sensitivity (95%) and specificity (65-75%) in the large majority of included studies. Sensitivity estimates varied from 19.8% (28) to 95.5% (8) and 57.7% (31) to 83.3% (30), for theoretical accuracy and real life triage performance respectively. Specificity results were similarly diverse ranging from 17.0% (27) to 93.1% (28) for theoretical accuracy, and 46.3% (31) to 78.9% (33) for actual paramedic decisions. There were no clear patterns evident for sensitivity between studies investigating theoretical accuracy and real-life transport decisions. However, specificity appeared to be lower for real-life transport decisions.

The studies at lowest risk of bias, with the best applicability, were Newgard *et al*. (27) (theoretical accuracy) and Voskens *et al*. (33) (real-life transport decisions). Sensitivity and specificity estimates from these studies were 37% and 90% (Field Triage Decision Scheme 2011), (27) and 61% and 79% (Dutch Field Triage Protocol), (33) respectively. Risk of bias and applicability concerns appeared to influence specificity estimates, with better results evident in studies with higher risk of bias, particularly those conducted using trauma registry data. No clear relationship was apparent between QUADAS-2 assessment and sensitivity estimates. In studies evaluating multiple triage tools, sensitivity increased, with a commensurate fall in specificity, as additional variables were added and less conservative variable thresholds were used. There were no obvious differences between individual triage tool performance; or the findings of studies with varying major trauma prevalence, age ranges, reference standards, study designs, or settings.

Overall quality of evidence

The GRADE quality of evidence was considered low quality based on: methodology (high or unclear risk of bias); heterogeneity (disparate and contradictory study results); and indirectness of evidence (study populations' not fully reflecting undifferentiated elderly pre-hospital patients). The quality rating was not affected by publication bias (no registered, but unpublished studies) or precision (relatively narrow 95% confidence intervals for included studies).

DISCUSSION

Summary of results

In a systematic review of 15 observational studies evaluating pre-hospital major trauma triage tools to identify suspected elderly trauma patients in need of specialized trauma care, we found that various triage protocols are being used but most lacked a rigorous evaluation. The diagnostic performance of the triage protocols was highly variable and differences in study design, study populations and reference standard make a comparison of the evidence difficult. Nevertheless, these findings raise concerns that existing pre-hospital triage tools used by paramedics fall below suggested ACS-COT triage targets and may not accurately identify elderly patients with serious injury.

Interpretation of results

Major trauma triage tools have two key roles. Firstly, for patients injured within the catchment area of a non-specialist general hospital they are used to select patients for bypass to MTCs. Secondly, for any patient, either injured closest to a MTC or a non-specialist hospital, they may inform 'standby calls' or pre-alerts to allow reception by a hospital trauma team in a resuscitation area. With current demographic trends transport of injured elders to the most suitable hospital is likely to be increasingly important. However, elderly patients have been highlighted as a subgroup of trauma patients who may be at risk of under-triage (38, 39). The findings of this review would support this view, with the majority of studies indicating substantial under- and over-triage. Moreover, the included studies with the lowest risk of bias and best applicability indicated sub-optimal sensitivity and specificity estimates of 37% and 90% (Newgard *et al.*, theoretical accuracy, Field Triage Decision Scheme 2011) (27), and 61% and

79% (Voskens *et al*., real-life transport decisions, Dutch Field Triage Protocol) (33), respectively.

Pre-hospital major trauma triage may be inaccurate in the elderly for a number of reasons. Firstly, elderly patients are frequently injured following ground level falls, or in the context of acute medical problems. Triage tools may consequently not be applied if injuries are not suspected after low energy mechanisms, or overlooked when focusing on ostensibly non-trauma presentations (40). Secondly, individual triage tools themselves may be inaccurate in elderly patients due to the confounding effects of frailty, aging, comorbidities, polypharmacy, and differing responses to injury. Physical and cognitive disability may limit the available history and challenge assessment of Glasgow Coma Score (GCS) (41). Normal physiological ranges, e.g. blood pressure, change during ageing so potentially resulting in sub-optimal cut-points for physiological triage variables (42). Elders frequently take medications that influence physiology (for example beta-blockers), or the sequelae of injury e.g. delayed bleeding secondary to anticoagulants (43). Furthermore, the response to injury may also be altered as a result of the ageing process e.g. initially higher GCS following expanding ICH due to brain involution and increased intracranial volume (44). Finally, pre-hospital clinicians will interpret the indicated triage tool result in light of clinical judgement and consideration of patient wishes.

Current triage tools generally consist of multiple variables applied in parallel, in which all need to be normal to give a negative result and any abnormal finding indicates a positive result. In this testing paradigm, as further variables are added sensitivity will increase, and specificity fall. The sensitivity and specificity can also be varied in opposite directions as the cut-point for variable positivity is altered. This is well illustrated by Newgard and colleagues (27) who developed a geriatric specific triage tool, adding comorbidity information and geriatric-specific physiologic measures to current US field triage guidelines. This demonstrated improve triage sensitivity for elders (37% to 90%), but with a substantial decrement in specificity (90% to 13%). However, false negative and false positive diagnoses are unlikely to be equally important in major trauma and the optimal trade-off between sensitivity and specificity may vary according to different perspectives. Ideally, in order to optimise triage tool performance, clinical costs and values would be accounted for to achieve the best balance of sensitivity and specificity. Metrics such as the weighted comparison index or net benefit would allow such calculations.

Major trauma is traditionally defined anatomically using an ISS threshold of >15. However, not all severely injured patients may benefit from advanced MTC care and this reference standard might not be appropriate for elderly patients. The premise that elders will have the same benefit from MTC care as younger adults is unproven, with the US Costs and Outcomes of Trauma study failing to identify a significant improvement in mortality for the elderly population (45). For patients with un-survivable injuries, or very severe comorbidities, outcomes may be fixed regardless of specialist care, making bypass away from local family support futile. For other injured elders, particularly in the context of advanced frailty, the probability of improved outcome may be low compared to the burden of treatment, and advanced MTC care might not be in a patients best interests. Patients and families may also prefer care closer to home in a local hospital and be willing to ‘trade’ better overall outcome to achieve this. Reference standards including resource use and frailty scores, might be used in future studies to give a better evaluation of triage performance in the elderly.

From a health services perspective, the effectiveness of pre-hospital triage is more important than theoretical accuracy of triage tools. This would be evaluated by whether patients injured closest to a non-specialist hospital are bypassed and if hospital trauma teams are activated appropriately for patients transported to a MTC. Such a viewpoint accounts for whether a triage tool is actually applied in practice, how clinical judgement is used to interpret observed triage tool variable values, and the influence of shared patient decision making or other contextual factors. Clinical judgement has been shown to be important in diagnosis across all fields of medicine and has been frequently demonstrated to outperform strict adherence to clinical decision rules. Unfortunately no studies were identified that investigated EMS clinician judgement in pre-hospital triage of elders with suspected major trauma; and studies looking at real life transport decisions were limited by inclusion of patients injured closest to a MTC.

This review included studies from a range established trauma systems in Western countries, and the findings should be largely generalisable to other similar health services in the developed world. However, it is important to note that our quality assessment overview highlights the limitations of the current literature. As such, further high-quality prospective observational cohort studies are needed. Some of the primary studies included highly selected populations (e.g. high risk road traffic accident patients or head injured patients) that may limit our ability to apply the findings to certain populations. Triage performance between countries could also vary due to geographical distance, compliance to protocols, and EMS training. External validity to triage by pre-hospital physicians or helicopter emergency medical services is less certain. Findings are also unlikely to be applicable to the developing world. It is important to recognise that the pre-test probability of major trauma will strongly influence the performance of triage tools. In settings with high prevalence of major trauma, or a high thresholds for applying triage tools, the negative predictive value will fall. High sensitivity and specificity would consequently be necessary to ensure the detection of a satisfactory proportion of cases. Conversely, indiscriminate application, with a lower pre-test probability of major trauma, would result in higher negative predictive values, but worsening numbers of false positives.

Given these challenges, how might triage of injured elders be improved? Firstly, the reference standard for triage decisions in elderly patients should reflect the need for direct MTC care rather than injury severity per se. This would help pre-hospital clinicians balance benefit and burden and identify the subset of elderly patients with major trauma who would benefit from bypass to MTCs and hospital trauma team activation. Secondly, it could be acknowledged that it may not be possible to achieve ACS-COT suggested triage targets for sensitivity (95%) and specificity (65-75%) for this revised reference standard. An optimal and achievable trade-off of under- and over-triage could be formulated based on clinical costs, benefits and patient preferences rather than arbitrary thresholds. Distinct triage criteria, with geriatric specific variables and thresholds, could then be developed to meet this objective. Thirdly, focusing on pre-hospital clinician training could improve real-life triage performance through better application of triage tools after low energy trauma or medical presentations, and honing clinical interpretation of triage variables. Fourthly, novel triage modalities including point of care testing or imaging may be increasingly possible in the future. Finally, trauma systems should ensure efficient processes for secondary transfer of any initially under-triaged patients.

Comparison to the existing literature

Several systematic reviews have been recently published that investigate pre-hospital major trauma triage, with two studies examining adults (10, 11) and one review focusing on children (9). Their findings are broadly similar to the current review, with widely heterogeneous results, high risk of bias, and sub-optimal sensitivity and specificity in the majority of included studies. Van Rein *et al.* (10) included 21 studies examining the theoretical accuracy of triage tool in injured adults, with sensitivity ranging from 10% to 100%; and specificity from 9% to 100%. The same group (11) also investigated real life triage decisions in adults with under-triage ranging from 1% to 68%, and over-triage from 5% to 99%, in 33 included studies. In children, van der Sluijs *et al.* (9) found that the sensitivity of prehospital triage tools ranged from 49.1% to 87.3%, and specificity from 41.7% to 84.8%, in five studies.

Strengths and limitations

This systematic review has a number of strengths. It is the first study to evaluate the performance of major trauma triage tools in the elderly, and was conducted with robust methodology in accordance with established guidelines for undertaking diagnostic accuracy systematic reviews (12, 13). However, there are a number of potential weaknesses. We did not perform hand searching (i.e. manual page-by-page examination of the entire contents) of journals or conference proceedings, and did not include regional bibliographic databases, although the yield of such searches is generally low. Inadequate reporting of non-randomised studies and poor indexing in databases may have impaired the detection of all published information. Decisions on study relevance, information gathering, and validity were un-blinded and could potentially have been influenced by pre-formed opinions. However, masking is resource intensive with uncertain benefits.

CONCLUSIONS

Studies of pre-hospital triage tools are at high risk of bias and report heterogeneous estimates for sensitivity and specificity. Triage accuracy generally fell below ACS-COT triage targets indicating that existing triage tools do not accurately identify severely injured elderly patients. Future work to improve pre-hospital trauma triage in elders could focus on: a more relevant reference standard reflecting the need for MTC care rather than injury severity; establishing the best trade-off between under- and over-triage; optimising the role pre-hospital clinician judgement; further developing geriatric specific triage variables and thresholds; and ensuring efficient processes for secondary transfer of any initially under-triaged patients.

Author contribution:

AP co-ordinated the study. GF, AP, JT and SK were responsible for conception, design and obtaining funding for the study. HBW developed the search strategy, undertook searches, and organised retrieval of papers. AP, ME, LS, HC, CH and GF were responsible for the acquisition, analysis and interpretation of data. GF, JT helped interpret and provided a methodological, policy and clinical perspective on the data. GF and AP were responsible for the drafting of this paper, although all authors provided comments on the drafts and read and approved the final version. GF is the guarantor for the paper.

Conflict of interest: None to declare

Source of funding: This study was funded by the United Kingdom National Institute for Health Research Health Technology Assessment Programme (project number 17/16/04). The views expressed in this report are those of the authors and not necessarily those of the NIHR HTA Programme. Any errors are the responsibility of the authors. The funders had no role in the study design, in the collection, analysis and interpretation of data; in the writing of the manuscript; and in the decision to submit the manuscript for publication.

REFERENCES

1. Kehoe A, Smith JE, Edwards A, Yates D, Lecky F. The changing face of major trauma in the UK. *Emerg Med J*. 2015;32(12):911-5.

2. World Health Organization. Prehospital trauma care systems: WHO, Geneva; 2005. Available from: https://www.who.int/violence_injury_prevention/publications/services/39162_oms_new.pdf. Accessed 05-11-2020.

3. National Institute for Health and Care Excellence (NICE). Major trauma: service delivery (NICE guideline 40): NICE, London; 2016 [Available from: https://www.nice.org.uk/guidance/ng40/chapter/Recommendations-for-research. Accessed 09-04-2020.

4. Moran CG, Lecky F, Bouamra O, Lawrence T, Edwards A, Woodford M, Willett K, Coats TJ, . Changing the System - Major Trauma Patients and Their Outcomes in the NHS (England) 2008–17. *EClinicalMedicine*. 2018;2-3:13-21.

5. Coats T, Lecky F. 'Major trauma': now two separate diseases? *Emerg Med J*. 2017;34(8):494.

6. Banerjee J, Baxter M, Coats T, Edwards A, Griffiths R, Kumar D, Lecky F, Sammy I , Wheldon A, M W. Major Trauma in Older People: The Trauma Audit & Research Network (TARN), Manchester; 2017.

7. Newgard CD, Richardson D, Holmes JF, Rea TD, Hsia RY, Mann NC, Staudenmayer K, Barton ED, Bulger EM, Haukoos JS, et al. Physiologic field triage criteria for identifying seriously injured older adults. *Prehosp Emerg Care*. 2014;18(4):461-70.

8. Cox S, Morrison C, Cameron P, Smith K. Advancing age and trauma: triage destination compliance and mortality in Victoria, Australia. *Injury*. 2014;45(9):1312-9.

9. van der Sluijs R, van Rein EAJ, Wijnand JGJ, Leenen LPH, van Heijl M. Accuracy of Pediatric Trauma Field Triage: A Systematic Review. *JAMA Surg*. 2018;153(7):671-6.

10. van Rein EAJ, Houwert RM, Gunning AC, Lichtveld RA, Leenen LPH, van Heijl M. Accuracy of prehospital triage protocols in selecting severely injured patients: A systematic review. *J Trauma Acute Care Surg*. 2017;83(2):328-39.

11. van Rein EAJ, van der Sluijs R, Raaijmaakers AMR, Leenen LPH, van Heijl M. Compliance to prehospital trauma triage protocols worldwide: A systematic review. *Injury*. 2018;49(8):1373-80.

12. Centre for Reviews and Dissemination. Systematic Reviews: CRD's Guidance for Undertaking Reviews in Health Care. York: Centre for Reviews and Dissemination; 2009.

13. Deeks JJ, Bossuyt PM, Gatsonis C, eds. Cochrane handbook for systematic reviews of diagnostic test accuracy version 1.0.0: The Cochrane Collaboration; 2013. Available from: http://srdta.cochrane.org/handbook-dta-reviews. Accessed 09-04-2020

14. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group, . Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med*. 2009;151:264-9.

15. Shenkin SD, Harrison JK, Wilkinson T, Dodds RM, Ioannidis JPA. Systematic reviews: guidance relevant for studies of older people. *Age Ageing*. 2017;46(5):722-8.

16. American College of Surgeons Committee on Trauma (ACS-COT). Resources for optimal care of the injured patient 2014. Chicago (IL): The Committee; 2014. Available from:

https://www.facs.org/-/media/files/quality-programs/trauma/vrc-resources/resources-for-optimal-care.ashx. Accessed 09-04-2020

17. Whiting PF, Rutjes AW, Westwood ME, Mallett S, Deeks JJ, Reitsma JB, Leeflang MM, Sterne JA, Bossuyt PM, QUADAS-2 Group. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. *Ann Intern Med* 2011;155:529-36.

18. McKenzie JE BS, Ryan RE, Thomson HJ, Johnston RV. Chapter 9: Summarizing study characteristics and preparing for synthesis. 2019. In: Cochrane Handbook for Systematic Reviews of Interventions version 6.0 (updated July 2019) [Internet]. Cochrane, 2019. Available from: https://training.cochrane.org/handbook. Accessed 09-04-2020

19. Schünemann HJ, Oxman AD, Brozek J, Glasziou P, Jaeschke R, Vist GE, Williams JW Jr, Kunz R, Craig J, Montori VM, et al. Grading quality of evidence and strength of recommendations for diagnostic tests and strategies. *BMJ*. 2008;336(7653):1106-10.

20. Gopalakrishna G, Mustafa RA, Davenport C, Scholten RJ, Hyde C, Brozek J, Schünemann HJ, Bossuyt PM, Leeflang MM, Langendam MW, et al. Applying Grading of Recommendations Assessment, Development and Evaluation (GRADE) to diagnostic tests was challenging but doable. *J Clin Epidemiol.* 2014;67:760–8.

21. Brown JB, Gestring ML, Forsythe RM, Stassen NA, Billiar TR, Peitzman AB, Sperry JL. Systolic blood pressure criteria in the National Trauma Triage Protocol for geriatric trauma: 110 is the new 90. *J Trauma Acute Care Surg*. 2015;78(2):352-9.

22. Ichwan B, Darbha S, Shah MN, Thompson L, Evans DC, Boulger CT, Caterino JM. Geriatric-specific triage criteria are more sensitive than standard adult criteria in identifying need for trauma center care in injured older adults. *Ann Emerg Med*. 2015;65(1):92-100.e3.

23. Jones CMC, Cushman JT, Anto-Ocrah M, Li T, Caterino JM, Wood N, Lenhardt H, Wasserman E, Gillespie S, Srinivasan V, et al. Validation of a novel prehospital decision tool to identify older adults at high risk for traumatic intracranial hemorrhage. Academic Emergency Medicine Conference: 2017 Annual Meeting of the Society for Academic Emergency Medicine, SAEM 2017 United states. 2017;24:S122.

24. Lavoie A, Emond M, Moore L, Camden S, Liberman M. Evaluation of the Prehospital Index, presence of high-velocity impact and judgment of emergency medical technicians as criteria for trauma triage. *CJEM*. 2010;12(2):111-8.

25. Newgard CD, Holmes JF, Haukoos JS, Bulger EM, Staudenmayer K, Wittwer L, Stecker E, Dai M, Hsia RY, Western Emergency Services Translational Research Network I. Improving early identification of the high-risk elderly trauma patient by emergency medical services. *Injury*. 2016;47(1):19-25.

26. Newgard CD, Hsia RY, Mann NC, Schmidt T, Sahni R, Bulger EM, Wang NE, Holmes JF, Fleischman R, Zive D, et al. The trade-offs in field trauma triage: a multiregion assessment of accuracy metrics and volume shifts associated with different triage strategies. *J Trauma Acute Care Surg*. 2013;74(5):1298-306.

27. Newgard CD, Lin A, Eckstrom E, Caughey A, Malveau S, Griffiths D, Zive D, Bulger E. Comorbidities, Anticoagulants, and Geriatric-Specific Physiology For the Field Triage of Injured Older Adults. *J Trauma Acute Care Surg*. 2019;86(5):829-837.

28. Nishijima DK, Gaona SD, Waechter T, Maloney R, Bair T, Blitz A, Elms AR, Farrales RD, Howard C, Montoya J, et al. Out-of-Hospital Triage of Older Adults With Head Injury: A Retrospective Study of the Effect of Adding "Anticoagulation or Antiplatelet Medication Use" as a Criterion. *Ann Emerg Med*. 2017;70(2):127-38.e6.

29. Phillips S, Rond PC, 3rd, Kelly SM, Swartz PD. The failure of triage criteria to identify geriatric patients with trauma: results from the Florida Trauma Triage Study. *J Trauma.* 1996;40(2):278-83.

30. Scheetz LJ. Effectiveness of prehospital trauma triage guidelines for the identification of major trauma in elderly motor vehicle crash victims. *J Emerg Nurs*. 2003;29(2):109-15.

31. Scheetz LJ. Trends in the accuracy of older person trauma triage from 2004 to 2008. *Prehosp Emerg Care*. 2011;15(1):83-7.

32. Scheetz LJ, Zhang J, Kolassa JE. Using crash scene variables to predict the need for trauma center care in older persons. *Res Nurs Health*. 2007;30(4):399-412.

33. Voskens FJ, van Rein EAJ, van der Sluijs R, Houwert RM, Lichtveld RA, Verleisdonk EJ, Segers M, van Olden G, Dijkgraaf M, Leenen LPH, et al. Accuracy of Prehospital Triage in Selecting Severely Injured Trauma Patients. *JAMA Surg.* 2018;153(4):322-7.

34. Nakamura Y, Daya M, Bulger EM, Schreiber M, Mackersie R, Hsia RY, Mann NC, Holmes JF, Staudenmayer K, Sturges Z, et al. Evaluating age in the field triage of injured persons. *Ann Emerg Med*. 2012;60(3):335-45.

35. Newgard CD, Fu R, Zive D, Rea T, Malveau S, Daya M, Jui J, Griffiths DE, Wittwer L, Sahni R, et al. Prospective Validation of the National Field Triage Guidelines for Identifying Seriously Injured Persons. *J Am Coll Surg*. 2016;222(2):146-58.e2.

36. Newgard CD, Zive D, Holmes JF, Bulger EM, Staudenmayer K, Liao M, Rea T, Hsia RY, Wang NE, Fleischman R, et al. A multisite assessment of the American College of Surgeons Committee on Trauma field triage decision scheme for identifying seriously injured children and adults. *J Am Coll Surg*. 2011;213(6):709-21.

37. Staudenmayer KL, Hsia RY, Mann NC, Spain DA, Newgard CD. Triage of elderly trauma patients: a population-based perspective. *J Am Coll Surg*. 2013;217(4):569-76.

38. Hoyle AC, Biant LC, Young M. Undertriage of the elderly major trauma patient continues in major trauma centre care: a retrospective cohort review. *Emerg Med J*. 2020;37(8):508-514.

39. Xiang H, Wheeler KK, Groner JI, Shi J, Haley KJ. Undertriage of major trauma patients in the US emergency departments. *Am J Emerg Med*. 2014;32(9):997-1004.

40. Fisher JM, Bates C, Banerjee J, . The growing challenge of major trauma in older people: a role for comprehensive geriatric assessment? *Age Ageing*. 2017;46(5):709-12. .

41. Lindner T, Slagman A, Senkin A, Möckel M, Searle J. Medical History of Elderly Patients in the Emergency Setting: Not an Easy Point-of-Care Diagnostic Marker. *Emerg Med Int*. 2015;2015:490947.

42. Boss GR, Seegmiller JE. Age-related physiological changes and their clinical significance. *West J Med*. 1981;135(6):434-40.

43. Evans DC, Gerlach AT, Christy JM, Jarvis AM, Lindsey DE, Whitmill ML, Eiferman D, Murphy CV, Cook CH, Beery PR 2nd, et al. Pre-injury polypharmacy as a predictor of outcomes in trauma patients. *Int J Crit Illn Inj Sci.* 2011;1(2):104-9.

44. Kehoe A, Smith JE, Bouamra O, Edwards A, Yates D, Lecky F. Older patients with traumatic brain injury present with a higher GCS score than younger patients for a given severity of injury. *Emerg Med J.* 2016;33:381–5.

45. Mackenzie EJ, Rivara FP, Jurkovich GJ, Nathens AB, Frey KP, Egleston BL, Salkever DS, Weir S, Scharfstein DO, . The National Study on Costs and Outcomes of Trauma. *J Trauma*. 2007;63:S54-S86.

Figure legends

Figure 1 Study flow chart

Figure 2 Theoretical accuracy of major trauma triage tools (sensitivity and specificity of triage tools when scored using observed patient variables)

Figure 3 Real-life performance of major trauma triage tools (sensitivity and specificity of triage tools when evaluated according to actual paramedic transportation decisions)

Table 1. Review question and inclusion criteria

Review Question	
What is the diagnostic performance of pre-hospital triage tools for identification of major trauma in elderly patients presenting to emergency medical services following injury?	
Inclusion Criteria	
Population	Elderly adults aged >60 years attended by land emergency medical services following injury with the potential for major trauma.
Index tests	Multivariable pre-hospital major trauma triage tools (either scored using observed patient variables or evaluated according to actual paramedic decision).
Reference standard	Any definition of major trauma, such as Injury Severity Score (ISS)
Outcomes	Diagnostic accuracy metrics including sensitivity, specificity, under-triage (1-sensitivity), over-triage (1-specificify), predictive values.
Study design	Diagnostic accuracy studies (prospective or retrospective)

Table 2. Study and population characteristics

Author, year	Design	Country	Sample size	Elderly definition	Population	Triage tool	Triage system	Definition of major trauma	Mean/median age	Male	Mechanism of injury	Blunt trauma	Major trauma prevalence
Phillips 1996(29)	R,CS	USA	3,116	>65	Unselected injuries	Florida Trauma Scorecard	Theoretical accuracy	MacKenzie definition	NR	NR	NR	NR	NR
Scheetz 2003(30)	R,CS	USA	463	≥65	MVA victims	New Jersey Trauma Guideline	Real-life decisions	ISS>15	75	49%	RTA: 100%	NR	22%
Scheetz 2007(32)	R,CS	USA	7,883	≥65	MVA victims	Novel tool	Theoretical accuracy	ISS>15	74	50%	RTA: 100%	NR	3%
Lavoie 2010(24)	R,CS	Canada	4,072	≥65	Unselected injuries	Montréal pre-hospital system	Theoretical accuracy	ISS>15, resource use, death	NR	NR	NR	NR	NR
Scheetz 2011(31)	R,CS	USA	166,685	≥55	MVA victims	a) FTDS 1999 b) FTDS 2006	Real-life decisions	AIS≥3	68	NR	RTA: 100%	NR	12%
Newgard 2013(26)	R,CS	USA	31,055	>60	Unselected injuries	Novel tool	Theoretical accuracy	ISS>15	81	34.6	Falls: 80%; RTA: 9%; other: 11%	99%	30%
Cox 2014(8)	R,CS	Australia	NR	>55	Unselected injuries	Victoria triage tool	Theoretical accuracy	ISS>12, resource use, death	NR	40%	Falls: 6%; RTA: 30%; Other/Missing: NR	NR	NR
Newgard 2014(7)	R,CS	USA	17, 804 [a]	≥55	Unselected injuries	FTDS 2011 (GCS ≤ 14)	Theoretical accuracy	ISS>15	NR	NR	NR	NR	NR
Brown 2015(21)	R,CS	USA	438,828	>65	Unselected injuries	a) FTDS 2011 (SBP < 110) b) FTDS 2011 (SBP < 90)	Theoretical accuracy	ISS>15, resource use, death	80	39%	NR	99%	32%
Ichwan 2015(22)	R,CS	USA	33,379	≥70	Unselected injuries	a) Ohio adult trauma criteria b) Ohio geriatric trauma criteria	Theoretical accuracy	ISS>15	82	31%	NR	99%	13%
Newgard 2016(25)	R,CS	USA	13,401	≥65	Unselected injuries	a) FTDS 2011 b) FTDS 2011 (modified)	Theoretical accuracy	ISS>15	NR	32.0%	Falls: 80%; RTA: 10%; other: 10%	NR	5%
Jones 2017(23)	P,CS	USA	4,295	≥55	Unselected injuries	a) Novel tool b) FTDS 2011	Theoretical accuracy	ICH	NR	41%	Falls: 75%; Other/Missing: NR	NR	4%
Nishijima 2017(28)	R,CS	USA	2,110	≥55	Head injured	a) FTDS 2011 b) FTDS 2011 (+ anticoags)	a)Theoretical accuracy b) Real-life decisions	ICH	73	60%	Falls: 72%; RTA: 17%; Other: 11%	100%	6%

Voskens 2018(33)	P,CS	Netherlands	1,085	>65	Unselected injuries	Dutch Field Triage Protocol	Real-life decisions	ISS>15	NR	NR	NR	NR	12%
Newgard 2019(27)	R,CS	USA	5,021	≥65	Unselected injuries	a) Novel tool b) FTDS 2011	Theoretical accuracy	ISS>15, resource use	82	33%	Falls: 83%; RTA: 8%; Other 9%	NR	6%

[a] Validation cohort

AIS, Abbreviated Injury Scale; Anticoags, anticoagulants; CS, cohort study; FTDS, Field Triage Decision Scheme; ISS, Injury Severity Score; MVA, motor vehicle accident; NR, not reported; P, prospective; R, retrospective; RTA, road traffic accidents

Table 3. QUADAS-2 quality assessment summary - Review authors' judgements

Author, year	Risk of bias				Applicability concerns		
	Patient selection	Index test	Reference standard	Flow and timing	Patient selection	Index test	Reference standard
Brown 2015(21)	HIGH	UNCLEAR	LOW	UNCLEAR	HIGH	LOW	LOW
Cox 2014(8)	LOW	HIGH	HIGH	UNCLEAR	HIGH	LOW	HIGH
Ichwan 2015(22)	HIGH	UNCLEAR	UNCLEAR	HIGH	HIGH	LOW	LOW
Jones 2017(23)	UNCLEAR	UNCLEAR	UNCLEAR	UNCLEAR	HIGH	LOW	HIGH
Lavoie 2010(24)	LOW	HIGH	HIGH	UNCLEAR	HIGH	LOW	LOW
Newgard 2013(26)	LOW	HIGH	UNCLEAR	UNCLEAR	LOW	LOW	LOW
Newgard 2014(7)	LOW	HIGH	UNCLEAR	UNCLEAR	HIGH	LOW	LOW
Newgard 2016(25)	LOW	HIGH	UNCLEAR	UNCLEAR	LOW	LOW	LOW
Newgard 2019(27)	UNCLEAR	UNCLEAR	UNCLEAR	HIGH	LOW	LOW	LOW
Phillips 1996(29)	UNCLEAR	HIGH	LOW	HIGH	LOW	LOW	LOW
Scheetz, Zhang, Kolassa, 2007(32)	LOW	HIGH	LOW	UNCLEAR	HIGH	HIGH	LOW
Scheetz & Monroe, 2003(30)	HIGH	LOW	UNCLEAR	UNCLEAR	HIGH	UNCLEAR	LOW
Scheetz 2011(31)	HIGH	LOW	LOW	UNCLEAR	HIGH	LOW	HIGH
Voskens 2018(33)	HIGH	LOW	LOW	LOW	LOW	LOW	LOW
Nishijima 2017(28)	HIGH	A) UNCLEAR [a] B) LOW [a]	UNCLEAR	UNCLEAR	HIGH	A) LOW [a] B) LOW [a]	HIGH

[a] Index test assessment of A) triage tool accuracy B) real-life triage tool performance