

Accuracy of major trauma triage using the MATTS tool: a cohort study

Gordon Fuller ¹, James Baird,² Esther Herbert,¹ Samuel Keating,¹ Joshua Miller ³, Richard Pilbery ⁴, Janette Turner ¹, Fiona Lecky,¹ Antoinette Edwards,⁵ Andy Rosser ³, Tia Callaghan,¹ Fiona Bell ⁴, Michael Smyth ⁶, Jason E Smith ^{7,8}, Gavin D Perkins,⁶ Stuart Reid,⁹ Mark Millins,⁴ Stephen J Walters,¹ Cindy Cooper,¹ MATTS Research Group

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¹School of Health and Related Research, University of Sheffield, Sheffield, UK

²London Ambulance Service NHS Trust, London, UK

³West Midlands Ambulance Service NHS Trust, Brierley Hill, UK

⁴Yorkshire Ambulance Service NHS Trust, Wakefield, UK

⁵Trauma Audit and Research Network, University of Manchester, Salford, UK

⁶Clinical Trials Unit, University of Warwick, Coventry, UK

⁷Emergency Department, University Hospitals Plymouth NHS Trust, Plymouth, UK

⁸Academic Department of Military Emergency Medicine, Royal Centre for Defence Medicine, Birmingham, UK

⁹Sheffield Teaching Hospitals NHS Foundation Trust, Sheffield, UK

Correspondence to

Dr Gordon Fuller;
g.fuller@sheffield.ac.uk

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ABSTRACT

Introduction The Major Trauma Triage Study ('MATTS') triage tool was designed to identify patients with major trauma who could benefit from expedited care in specialist major trauma centres (MTCs). We aimed to investigate the impact of the MATTS tool on major trauma triage decisions after implementation.

Methods Consecutive patients were included in a multicentre, prospective cohort study conducted between 1 November 2021 and 15 May 2022 in six trauma networks served by West Midlands and Yorkshire Ambulance Services. Electronic data from ambulance service patient report forms were linked to data from the Trauma Audit and Research Network trauma registry. The accuracy of prehospital triage decisions (conveyance to an MTC with pre-alert) against a bespoke MATTS reference standard to define major trauma was calculated. This was compared with optimal undertriage/overtriage trade-off indicated by previous economic modelling. Additional analyses investigated theoretical triage tool accuracy based on recorded data irrespective of hospital destination, examined important injury subgroups, evaluated alternative reference standards and described triage tool use.

Results In total, 38 010 injured patients were included, with 2.2% prevalence of major trauma. The MATTS triage tool demonstrated 55.3% sensitivity (95% CI 51.8% to 58.7%) and 94.3% specificity (95% CI 94.1% to 94.6%). There was evidence of triage tool use in a minority of patients (6.3%), with senior clinical advice sought in 9.3% of patients. Theoretical triage tool sensitivity was 51.1% (95% CI 47.6% to 54.5%) with specificity 93.6% (95% CI 92.7% to 94.4%). Agreement between the theoretical triage tool result and the observed triage decision was good (absolute agreement 90.4%, Gwet's agreement coefficient 1 (AC1) statistic 0.89, 95% CI 0.89 to 0.89). Accuracy varied across different ages, mechanisms of injury subgroups and alternative reference standards for major trauma.

Conclusions The MATTS triage tool achieved an appropriate undertriage/overtriage trade-off compared with previously established targets. However, documented adherence to MATTS was low. Dedicated training and further evaluation are necessary prior to national wider implementation.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ There are many existing major trauma triage tools which differ in format, structure, variables and cut points. The target trade-off between sensitivity and specificity and the target type of major trauma are usually not specified.

WHAT THIS STUDY ADDS

⇒ The performance of a candidate national major trauma triage tool for use in the English National Health Service was evaluated. The tool targeted a bespoke reference standard reflecting the need for early major trauma centre care and prioritised relatively high specificity to sensitivity trade-off, established through economic modelling.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The MATTS triage tool achieved an appropriate undertriage/overtriage trade-off compared with targets indicated from previous economic modelling. The tool was introduced without a dedicated training programme, and it was unclear if it was routinely used in daily practice. Clinician education and further evaluation may therefore be required prior to national implementation to ensure standardised, cost-effective and evidence-based triage across trauma networks.

INTRODUCTION

There is currently wide variation in major trauma triage across the UK National Health Service (NHS)¹; with each regional ambulance service using a different triage tool. While this could appropriately reflect local circumstances, the variability may contribute to suboptimal outcomes.² Consequently, the National Institute for Health and Care Excellence recommended research to develop a national major trauma triage tool.³

The Major Trauma Triage Study (MATTS) project was consequently commissioned and developed a candidate new major trauma triage tool through an expert consensus process following examination of available tools, qualitative research examining how major trauma triage currently works and review of

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available evidence.⁴ The tool targeted a bespoke reference standard reflecting the need for early major trauma centre (MTC) care and prioritised relatively high specificity to sensitivity trade-off, established through economic modelling (target sensitivity 57%; specificity 80%).⁵ External validation of theoretical triage tool performance, in comparison to other UK and international tools, suggested that the MATTS triage tool was optimally performing at typical cost-effective willingness to pay thresholds (£20 000–30 000/quality adjusted life years).

The aim of the current management outcome study was to investigate major trauma triage using the MATTS tool following implementation in English ambulance services. Specific objectives were to establish the accuracy of ambulance service triage decisions; determine the theoretical accuracy of the MATTS triage tool and quantify agreement with real-life triage decisions; examine triage tool use, including senior clinical advice; evaluate performance across important injury subgroups.

METHODS

Study design

A multicentre, prospective cohort study, with nested case-cohort substudy,⁶ was conducted to evaluate the performance of a newly introduced major trauma triage tool. Study procedures followed consensus recommendations for the conduct and reporting of diagnostic accuracy studies.^{7 8}

Study setting

The study was conducted between 1 November 2021 and 15 May 2022 in six inclusive trauma networks served by the West Midlands (WMAS) and Yorkshire Ambulance Services (YAS), serving a total population of 10.6 million people. Patients injured in the catchment areas of all major MTCs and the majority of non-MTCs were included. Non-MTCs served primarily by a non-study ambulance service or with incomplete submissions to the Trauma Audit and Research Network (TARN) were not included. Full details are provided in the supplementary materials (online supplemental table S1 and online supplemental figure S1).

Study intervention

A new triage tool (termed the 'MATTS tool') was implemented in WMAS and YAS on 25 October 2021 and 1 October 2021, respectively.⁵ The triage tool was introduced through each ambulance service's weekly email briefing and distributed in electronic

and paper-based versions, prior to implementation. Formatting differed slightly across each service as presented in figure 1. Adherence to the triage tool was expected as the standard of care. However, compliance was not mandatory, and deviations were permitted when clinically justified.

Study population

The source population comprised consecutive injured patients of any age presenting to participating ambulance services and trauma networks. From this, two study populations were examined: (a) the main cohort and (b) a nested case-cohort sample.

Consecutive patients were included in the main cohort if they were conveyed to hospital following an injury, by land or air ambulance. Injured patients were identified by injury-related diagnostic working impression codes, use of a trauma-related prehospital intervention, or activation of a major trauma emergency department (ED) pre-alert. Full details of inclusion and exclusion criteria are provided in the supplementary materials (online supplemental table S2 and online supplemental figure S2).

An additional case-cohort sample was delimited for more detailed data collection to allow full characterisation of the study cohort and additional analyses examining injury mechanism subgroups, theoretical triage tool performance and triage compliance. This comprised a random sample of injured patients presenting to ambulance services together with any non-sampled major trauma cases. Further details on the case-cohort study design are included in the supplementary materials (online supplemental figures S3 and S4).

Data collection

Prehospital data were collected from ambulance service electronic patient report (EPR) forms including ambulance service identifiers, demographics, patient characteristics, physiology, incident details, mechanism of injury, interventions, treatments and clinical assessment information. The primary variables of interest were incident location, hospital destination and ED pre-alert status. Major trauma status was determined using data from TARN, the English national trauma registry. TARN data collection has been reported in detail previously.^{9 10} Data linkage between eligible injured ambulance service cases and TARN cases was conducted deterministically based on a unique ambulance service patient report form number shared across both datasets. In cases where exact deterministic matching was

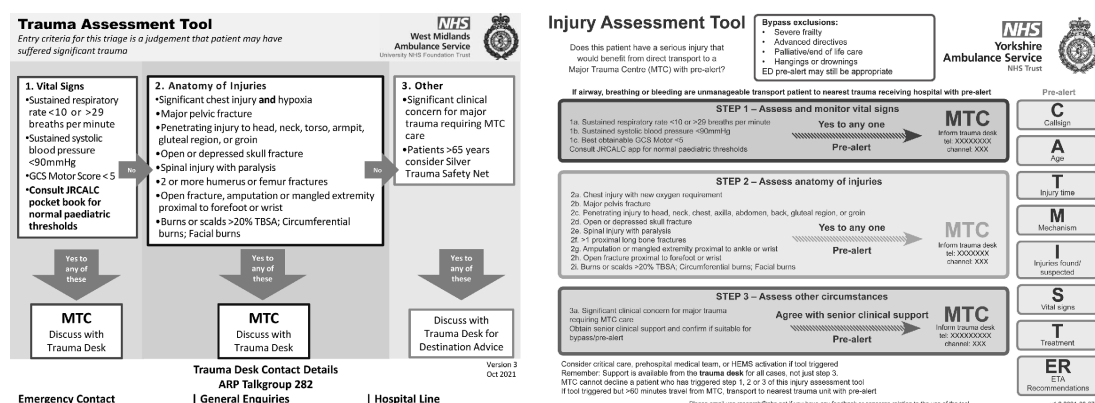


Figure 1 MATTS triage tool implemented in WMAS and YAS. ETA, estimated time of arrival; GCS: Glasgow Coma Scale; HEMS, Helicopter Emergency Medical Services; JRCALC: Joint Royal Colleges Ambulance Liaison Committee; oma Scale; JRCALC: Joint Royal Colleges Ambulance Liaison Committee; MATTS, Major Trauma Triage Study; NHS, National Health Service; TBSA: total body surface area; WMAS, West Midlands; YAS, Yorkshire Ambulance Services.

not possible due to missing or inaccurate patient report form number, research paramedics performed probabilistic matching by manually reviewing demographic, non-unique ambulance identifiers (computer aided dispatch numbers, ambulance call sign) and incident information data. All matches were independently confirmed by a second researcher and a match was not confirmed in the presence of any uncertainty or disagreement.

The random sample of eligible ambulance service patients and all eligible major trauma cases underwent additional hand coding by research paramedics in the nested case-cohort sample.⁶ This provided additional information beyond that available in closed EPR fields including patient characteristics, injury mechanisms and details on individual triage tool criteria.

Data abstraction was blinded with all ambulance service data anonymised and reference standard status not available. A data dictionary was developed a priori to standardise all data elements, provide variable definitions and define categorisations. Data were recorded as missing if not present in closed fields or if not possible to infer from free text fields.

Reference standards

In the primary reference standard, major trauma was defined according to a previously established consensus definition developed earlier in the MATTS project (the 'MATTS reference standard').¹¹ This reference standard included the need for a time-critical trauma intervention, significant individual injuries and polytrauma requiring expedited MTC care as detailed in the supplementary materials (online supplemental table S3). Other secondary reference standard definitions for major trauma were also examined including Injury Severity Score (ISS) ≥ 16 ,¹² the US consensus standard for trauma centre need (online supplemental table S4)¹³ and the MATTS reference standard without open fractures. Major trauma status was established from TARN data. ISS was precalculated by TARN by trained injury coders using standardised procedures. Other secondary reference standards were algorithmically coded centrally by the research team.

Index tests

In the main cohort, the accuracy of prehospital triage decisions for detecting major trauma was examined as the primary

index test. Prehospital triage decisions were deemed positive for suspected major trauma if the patient was conveyed to a MTC with a pre-alert and negative if conveyed to a non-MTC hospital (trauma unit or local emergency hospital) or MTC without pre-alert. The triage pathway was defined algorithmically based on travel distance between the incident location and the nearest and destination hospitals.

In the case-cohort subpopulation, theoretical triage tool performance was examined. This was based on research paramedics coded ambulance data (positive triage tool variable vs no objective evidence of a positive triage variable), irrespective of actual hospital destination, clinical judgement or pre-alert status.

Outcomes

Diagnostic accuracy of index tests against reference standards was evaluated using sensitivity, specificity, positive and negative predictive values and likelihood ratios, together with their 95% CIs. Triage compliance was investigated, comparing absolute and chance-corrected agreement (Gwet's AC1 with 95% CI) between the theoretical triage tool result and the actual triage decision. The proportion of cases with objective evidence of triage tool use and senior clinical support, indicated within the clinical record, was also investigated.

Analyses

The analysis proceeded in eight stages. First, the derivation of the main cohort and case-cohort populations were delineated. Second, sample characteristics were examined using descriptive statistics. Third, in the main cohort, the accuracy of prehospital triage decisions against the MATTS reference standard for major trauma was calculated. Fourth, in the case-cohort population, theoretical triage tool performance was examined against the primary MATTS reference standard. Fifth, subgroup analyses were performed in different age (main cohort: children, <16 years; adults, 16–64 years; and elderly, ≥ 65 years), geographical (main cohort: rural, urban) and injury (case-cohort population: blunt vs penetrating trauma and low (falls <2m, low velocity blunt trauma) vs high (falls >2m, high velocity blunt trauma, penetrating trauma) energy injury) subgroups. Sixth, in sensitivity analyses, alternative definitions for prehospital triage

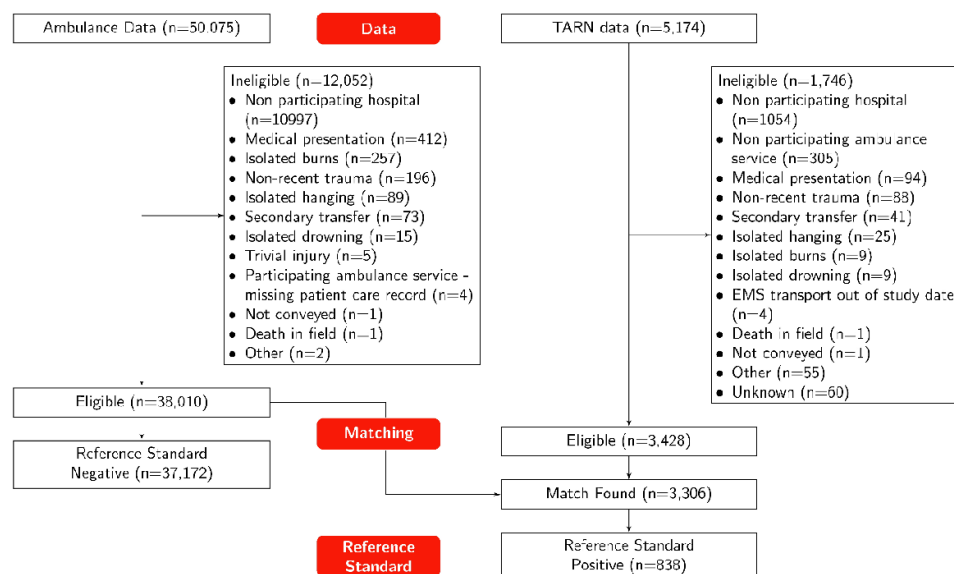


Figure 2 Derivation of primary reference standard positive and negative patients in the main cohort. EMS, Emergency Medical Services; TARN, Trauma Audit and Research Network.

decisions (MTC vs non-MTC hospital) and major trauma were examined ($ISS \geq 16$, the US consensus standard for MTC need and the MATTS reference standard without open fractures). Seventh, triage compliance was examined, comparing agreement between the theoretical triage tool result and the actual triage decision (case-cohort population: conveyed to MTC with pre-alert vs other triage pathway). Finally, the proportion of cases

where there was evidence of triage tool use was described (case cohort population).

Analyses were conducted in R Statistical Software (V.4.3.0; R Core Team 2023) and STATA V.18.0 (StataCorp, 2023, Stata Statistical Software: V.18. College Station, Texas, USA). Complete case analyses were performed, with inverse probability sampling weighting used in case-cohort analyses.

Table 1 Characteristics of the main study cohort

		Reference standard negative n=37 172	Reference standard positive n=838	Total n=38 010
Age (years)	n	36 964	838	37 802
	Mean (SD)	64.7 (25.6)	56.8 (23.6)	64.5 (25.6)
	Median (IQR)	74.0 (46.0–85.0)	60.0 (36.2–77.0)	74.0 (46.0–85.0)
	Min, max	0, 111	0, 99	0, 111
Sex	n	36 357	817	37 174
	Male	17 245 (47.4%)	502 (61.4%)	17 747 (47.7%)
	Female	19 112 (52.6%)	315 (38.6%)	19 427 (52.3%)
GCS total	n	34 426	731	35 157
	Mean (SD)	14.6 (1.3)	13.5 (3.3)	14.6 (1.4)
	Median (IQR)	15.0 (15.0–15.0)	15.0 (14.0–15.0)	15.0 (15.0–15.0)
	Min, max	3, 15	3, 15	3, 15
Systolic blood pressure (mm Hg)	n	33 622	681	34 303
	Mean (SD)	143.4 (27.5)	136.5 (31.9)	143.3 (27.6)
	Median (IQR)	142.0 (125.0–161.0)	136.0 (118.0–156.0)	142.0 (124.5–161.0)
	Min, max	0, 256	0, 239	0, 256
Respiratory rate (breaths per minute)	n	35 308	740	36 048
	Mean (SD)	18.8 (4.7)	20.7 (6.5)	18.8 (4.8)
	Median (IQR)	18.0 (16.0–20.0)	20.0 (18.0–24.0)	18.0 (16.0–20.0)
	Min, max	0, 136	0, 72	0, 136
Oxygen saturation (on air)	n	23 766	452	24 218
	Mean (SD)	96.6 (4.0)	93.7 (9.7)	96.5 (4.2)
	Median (IQR)	97.0 (96.0–98.0)	96.0 (93.0–98.0)	97.0 (96.0–98.0)
	Min, Max	0, 109	0, 100	0, 109
Oxygen saturation (on oxygen)	n	461	84	545
	Mean (SD)	91.7 (12.1)	96.3 (5.0)	92.4 (11.4)
	Median (IQR)	95.0 (89.0–99.0)	98.0 (96.0–99.0)	96.0 (90.0–99.0)
	Min, ax	0, 100	79, 100	0, 100
Injury place	n	12 117	825	12 942
	Home	7497 (61.9%)	374 (45.3%)	7871 (60.8%)
	Residential institution	1014 (8.4%)	19 (2.3%)	1033 (8.0%)
	School, other institution or public administrative area	89 (0.7%)	4 (0.5%)	93 (0.7%)
	Medical hospital or health service	62 (0.5%)	1 (0.1%)	63 (0.5%)
	Athletics or sports area	165 (1.4%)	9 (1.1%)	174 (1.3%)
	Road, street or highway	1888 (15.6%)	306 (37.1%)	2194 (17.0%)
	Trade or service area	270 (2.2%)	24 (2.9%)	294 (2.3%)
	Industrial or construction area	31 (0.3%)	10 (1.2%)	41 (0.3%)
	Farm	24 (0.2%)	13 (1.6%)	37 (0.3%)
	Place for recreation	164 (1.4%)	32 (3.9%)	196 (1.5%)
	Other	913 (7.5%)	33 (4.0%)	946 (7.3%)
Injury intent	n	8993	788	9781
	Assault	623 (6.9%)	69 (8.8%)	692 (7.1%)
	Accident	7800 (86.7%)	643 (81.6%)	8443 (86.3%)
	Intentional self-harm	258 (2.9%)	35 (4.4%)	293 (3.0%)
	Other	312 (3.5%)	41 (5.2%)	353 (3.6%)
Attendance	Technician	2821 (60.1%)	406 (48.4%)	3227 (58.3%)
	Paramedic	4047 (86.2%)	762 (90.9%)	4809 (86.9%)
	Critical care paramedic	53 (1.1%)	98 (11.7%)	151 (2.7%)
	Helicopter emergency medical services	31 (0.7%)	100 (11.9%)	131 (2.4%)
	Physician	34 (0.2%)	81 (9.7%)	115 (0.6%)

Sample size calculation

An a priori sample size calculation assumed a major trauma prevalence of 0.8% and triage performance of sensitivity 95% and specificity of $\geq 70\%$ based on American College of Surgeons Committee on Trauma (ACS-COT) targets.^{14 15} A sample of 57 125 injured patients, including 457 major trauma cases, would be required to provide a 95% CI coverage of 2.0% for sensitivity and $<1\%$ for specificity. Ambulance services estimated from pilot work approximately 150 000 injury incidents over 6 months across the participating trauma networks. For the nested case-cohort study a census sample of major trauma cases would include 457 cases. A sampling fraction of 9.5% of the 57 125 injured patients would include 5384 cases without major trauma (and sample 43 major trauma cases already identified). This would provide a 95% CI coverage of 2.0% for sensitivity and $<1\%$ for specificity.

Public and patient involvement

Public and patient involvement (PPI) was included at all stages of the MATTS project from inception to dissemination and was provided by the Sheffield Emergency Care Forum, Birmingham injuries and AfterTrauma PPI groups; a project service user advisory group, lay co-investigators and project steering group PPI representatives. Input included proposal development, study

management, reference standard and triage tool development, development and review of study outputs. Triage accuracy targets, based on economic modelling and favouring relatively higher specificity, were reviewed and agreed with PPI collaborators. Full details of PPI contributions at each stage of the project are provided in the supplementary materials (online supplemental table S5).

RESULTS

Sample derivation and characteristics

Between 1 November 2021 and 15 May 2022, 38 010 ambulance service injured patients met study inclusion criteria, of whom 838 were identified in TARN data and had major trauma meeting the primary reference standard definition (2.2%, 95% CI 2.06 to 2.36). Derivation of the main cohort is detailed in figure 2. From the parent cohort, 4390 patients (838 cases, 3552 non-cases) were included in the case-cohort subpopulation as detailed in the supplementary materials (online supplemental table S5).

Included patients presenting to ambulance services with injury were predominantly elderly (median age 74 years), female (52.3%) and sustained accidental (86.3%) blunt trauma (88.9%) from ground level falls (64.8% of injury mechanisms).

Table 2 Accuracy of triage decisions (conveyance to MTC with pre-alert) for major trauma (MATTS primary reference standard) both overall and in important subgroups

Triage decision*	Reference standard negative	Reference standard positive	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
Main cohort to primary MATTS reference standard						
N	37 167	838	55.3% (51.8% to 58.7%)	94.3% (94.1% to 94.6%)	18.0% (16.5% to 19.5%)	98.9% (98.8% to 99.0%)
Negative	35 060 (94.3%)	375 (44.7%)				
Positive	2107 (5.7%)	463 (55.3%)				
Elderly subgroup to primary MATTS reference standard						
N	22 265	378	42.3% (37.3% to 47.5%)	96.1% (95.8% to 96.3%)	15.5% (13.3% to 17.7%)	99.0% (98.9% to 99.1%)
Negative	871 (3.9%)	160 (42.3%)				
Positive	2107 (5.7%)	463 (55.3%)				
Adult subgroup to primary MATTS reference standard						
N	13 008	429	65.7% (61.0% to 70.2%)	91.5% (91.0% to 92.0%)	20.3% (18.2% to 22.4%)	98.8% (98.6% to 99.0%)
Negative	11 902 (91.5%)	147 (34.3%)				
Positive	1106 (8.5%)	282 (65.7%)				
Paediatric subgroup to primary MATTS reference standard						
N	1686	31	67.7% (48.6% to 83.3%)	93.4% (92.1% to 94.5%)	15.8% (9.6% to 22.0%)	99.4% (99.0% to 99.8%)
Negative	1574 (93.4%)	10 (32.3%)				
Positive	112 (6.6%)	21 (67.7%)				
Rural subgroup to primary MATTS reference standard						
N	5441	186	55.4% (47.9% to 62.7%)	95.4% (94.8% to 95.9%)	29.0% (24.3% to 33.7%)	98.4% (98.1% to 98.8%)
Negative	5189 (95.4%)	83 (44.6%)				
Positive	252 (4.6%)	103 (55.4%)				
Urban subgroup to primary MATTS reference standard						
N	31 159	652	55.2% (51.3% to 59.1%)	94.2% (93.9% to 94.4%)	16.5% (14.9% to 18.1%)	99.0% (98.9% to 99.1%)
Negative	29 337 (94.2%)	292 (44.8%)				
Positive	1822 (5.8%)	360 (55.2%)				

*TU/LEH/MTC with no pre-alert MTC with pre-alert.

MATTS, Major Trauma Triage Study; MTC, major trauma centre; NPV, negative predictive value; PPV, positive predictive value.

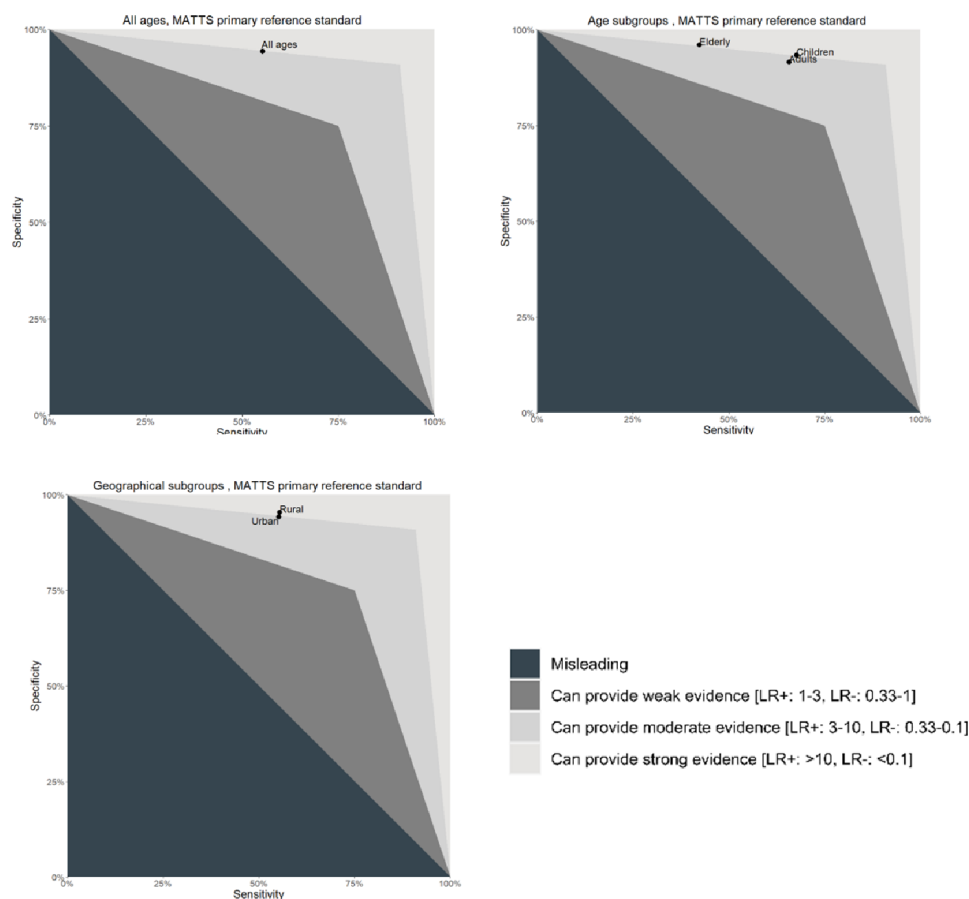


Figure 3 Sensitivity/specificity plots showing accuracy of triage decisions* for major trauma (defined by the MATTS primary reference standard) in the main cohort. *Positive triage decisions: (1) injured within catchment area of non-MTC and bypassed to MTC with pre-alert; (2) injured within catchment area of MTC and transported there with pre-alert; negative triage decisions: (1) injured within catchment area of non-MTC and conveyed to that hospital; (2) injured within catchment area of MTC and transported there without pre-alert. LR, likelihood ratio; IMATTS, Major Trauma Triage Study; MTS, major trauma centre

Characteristics of the main cohort population are presented in [table 1](#). Attributes of the case-cohort subpopulation, and further details on eligibility, data completeness and unmatched cases are provided in the supplementary materials (online supplemental tables S6–S8).

Prehospital triage decisions

In the primary analysis, prehospital triage decisions, in terms of conveyance to a MTC with an ED pre-alert, demonstrated a sensitivity of 55.3% (95% CI 51.8% to 58.7%), specificity of 94.3% (95% CI 94.1% to 94.6%), positive predictive value of 18.1% (95% CI 16.5% to 19.5%) and negative predictive value of 98.9% (95% CI 98.8% to 99.0%) for major trauma defined by the MATTS reference standard ([table 2](#) and [figure 3](#)).

No significant differences in triage performance were observed between rural and urban areas. The accuracy of prehospital triage decisions varied across different age subgroups with lower sensitivity and higher specificity evident in elderly patients compared with children and adults aged 16–65 years ([table 2](#) and [figure 3](#)). Prehospital triage accuracy also varied across different mechanisms of injury subgroups. Sensitivity was much higher for penetrating (95.0%) and high energy trauma (68.7%) compared with blunt (52.2%) and low energy trauma (29.5%); with correspondingly lower specificity (75.2% vs 94.0%; and 85.4% vs 96.4%, respectively). Full details are presented in the supplementary materials (online supplemental table S9). Sensitivity

analyses examining alternative definitions for prehospital triage decisions and major trauma are also detailed in the supplementary materials (online supplemental tables S10–S12).

Theoretical triage tool accuracy

The diagnostic accuracy of theoretical triage tool results demonstrated sensitivity of 51.1% (95% CI 47.6% to 54.5%), specificity of 93.6% (92.7–94.4%), positive predictive value of 15.2% (95% CI 12.5% to 18.0%), and negative predictive value of 98.8% (98.5–99.2%). Theoretical diagnostic accuracy results calculated for age strata, geographical settings, injury mechanism subgroups and secondary reference standards demonstrated a similar qualitative pattern to that reported for prehospital triage decisions, as detailed in the supplementary materials (online supplemental table S13). Sensitivity analyses examining alternative definitions for major trauma are detailed in the supplementary materials (online supplemental table S14).

Triage tool use

It was unclear whether the triage tool had been used in most cases (2941/4390, population weighted proportion 65.5%), with clear evidence of use present for 445/4390 (weighted proportion 6.3%). Senior clinical advice was documented in 707/4390 of patients (weighted proportion 9.3%). There was good agreement between the theoretical triage tool result and the observed triage

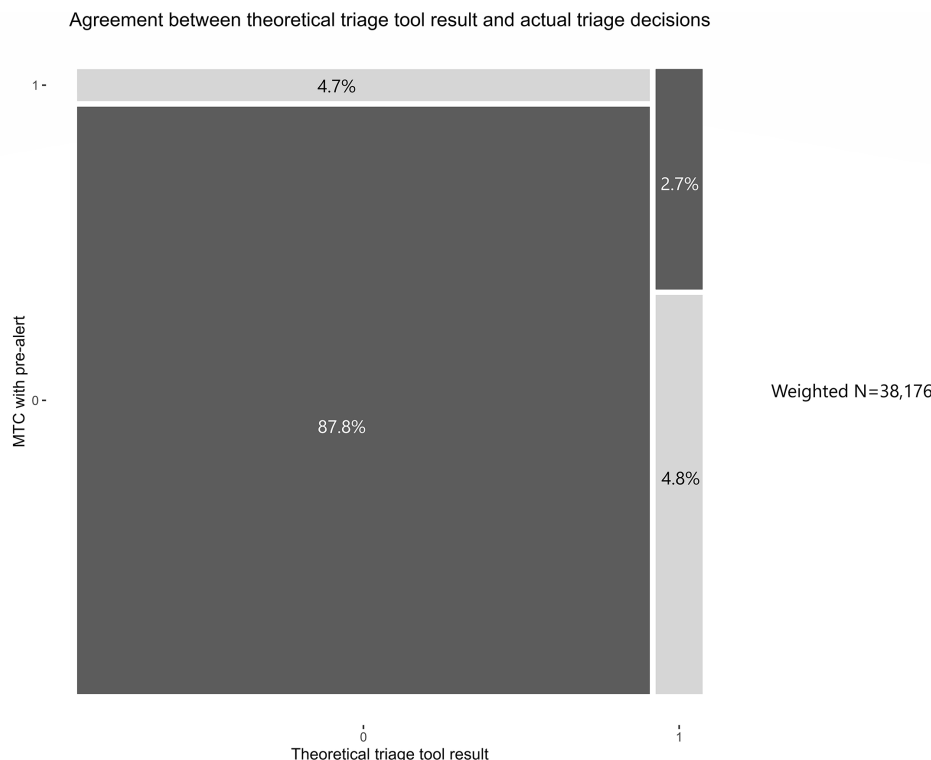


Figure 4 Mosaic plot showing agreement between triage decision (MTC pre-alert or not) and theoretical triage tool result. Results weighted for case-cohort study design. *Positive triage decisions: (1) injured within catchment area of non-MTC and bypassed to MTC with pre-alert, (2) injured within catchment area of MTC and transported there with pre-alert; negative triage decisions: (1) injured within catchment area of non-MTC and conveyed to that hospital; (2) injured within catchment area of MTC and transported there without pre-alert. MTC, major trauma centre

decision, with 3842/4390 patients having concordant outcomes (population weighted data, 90.4% absolute agreement, Gwet's AC1 statistic 0.89, 95% CI 0.89 to 0.89, figure 4).

DISCUSSION

Summary

There was low prevalence of major trauma in injured patients presenting to ambulance services (2.2%). Prehospital triage decisions using the new MATTS triage tool demonstrated a sensitivity of 55.3% (95%CI 51.8% to 58.7%) and specificity of 94.3% (95% CI 91.4% to 94.6%). There was evidence of triage tool use in a minority of patients (6.3%), with senior clinical advice sought in 9.3% of cases. There were notable differences in the accuracy of triage decisions across different ages, mechanisms of injury subgroups and alternative reference standards for major trauma.

Interpretation

The ACS-COT recommends minimising undertriage (1—sensitivity, $\leq 5\%$) while accepting higher overtriage (1—specificity, $\leq 35\%$).¹⁶ However, these targets require careful interpretation. Diagnostic accuracy varies with population (spectrum effects), and overtriage may be better measured by the false discovery fraction, reflecting the burden of false positive cases to MTCs.¹⁷ There are also inevitable trade-offs between sensitivity and specificity as the threshold for bypassing/pre-alerting is changed. Rather than using an arbitrary cut-off, the optimal balance is best determined by full consideration of the costs and consequences of false positives and negatives.¹⁸ Economic evidence suggests prioritising specificity,^{5 19–21} and accuracy estimates will depend on how triage decisions and major trauma are defined.²²

Although at face value, triage decisions using the MATTS triage tool fell well short of the ACS-COT undertriage target,¹⁴ the observed triage tool specificity is consistent with recommendations to minimise the false positive fraction (ie, fewer false positive cases unnecessarily conveyed and pre-alerted to MTCs),^{5 16} has been shown to be cost-effective at plausible willingness to pay thresholds and has been received positively by trauma networks. Of note, triage tool performance was favourable for important subgroups including children, penetrating trauma and high acuity major trauma cases meeting the US consensus criteria for trauma centre need; significantly altering the post-test probability to cross credible probability thresholds to rule in ($\geq 20\%$) or rule out ($\leq 1\%$) major trauma (see online supplemental figure S6 for further details). Low sensitivity was evident in elderly major trauma, but the benefit of MTC care is less clear cut in this subgroup.^{17–19} Moreover, there was a very low proportion of false negative cases with ISS ≥ 16 that required time-critical interventions (n=3/422, 0.7%, US consensus criteria) suggesting lower acuity in these false negative cases with the opportunity for secondary transfer if required.

It was often unclear from prehospital records whether the triage tool had been used. This may reflect the observational study design, with lack of data recording, rather than lack of tool use. A different study design, with direct observation of use, would be required to accurately capture this. Alternatively, uptake may have been limited, as the tool was introduced without dedicated training and may not have been fully embedded in practice. Qualitative research also suggests that prehospital providers consult triage tools infrequently, making largely heuristic triage decisions.²³ National implementation of the MATTS tool might therefore have a limited impact on

trauma network flows and patient outcomes. Despite this, there was good agreement between theoretical triage tool results and actual triage decisions, indicating a strong alignment with clinical judgement. Prior work suggests that clinical judgement improves triage performance, and there was a small, but statistically non-significant, increase in sensitivity (55% vs 51%) and specificity (93.6% vs 94.3%) with real-life triage decisions. Senior clinical advice, obtained in half of major trauma cases, may have contributed to improved detection.

Comparison to the previous literature

Two systematic reviews have examined major trauma triage decisions in adults using hospital destination as the index test and serious injury (mostly ISS ≥ 16) as the reference standard.^{20 21} The most valid study by Newgard *et al*²² reported a prevalence of 3.3% for ISS ≥ 16 , sensitivity of 64% and specificity of 70% for inclusive US trauma systems using the 2006 Field Triage Decision Scheme.²² Lokerman *et al*²³ found similar results using an app-based prediction model in the Netherlands²³; with prevalence of 2.5/2.9%, sensitivity 68/73% and specificity 68/73%, before and after app introduction. Direct comparison is limited by differences in prevalence of major trauma and distribution of patients between catchment areas of MTCs and non-MTCs. However, the findings are comparable to the relevant secondary analysis of the current study (prevalence 2.5%, sensitivity 66%, specificity 62%).

Strengths and limitations

This study has several strengths including objective index test determination, detailed data collection, comprehensive and successful matching process (>95%, no differences between matched and unmatched cases), large sample size, exploration of multiple reference standards and conformity with diagnostic study design and conduct recommendations. However, there are limitations that could influence internal validity. Correct reference standard classification was dependent on TARN inclusion criteria, case ascertainment, complete data collection and accurate matching of TARN and prehospital data. There is a small risk of selection bias from inaccurate working impression codes and missing data (triage tool analysis only); information bias from use of routine data and possible differential verification bias for reference standards including urgent trauma interventions. A full critical appraisal of potential biases, classified according to Quality Assessment of Diagnostic Accuracy Studies-2 criteria, is provided in the supplementary materials (online supplemental table S15).

The six included trauma networks (comprising 8/26 English MTCs) covered varied urban, rural and socioeconomic settings, but differences in service delivery—such as prehospital physician availability and MTC configuration—may limit generalisability across the UK. Triage accuracy also varied by injury mechanism, so performance may differ in populations with different trauma profiles. Applicability to other settings may be further affected by differences in EMS organisation, demographics, medicolegal context and the costs and consequences of undertriage and overtriage.

CONCLUSIONS

The MATTS triage tool has been specifically developed for NHS use, targets an appropriate undertriage/overtriage trade-off and has been received favourably by stakeholders. However, the tool was introduced without a dedicated training programme and there was limited evidence of triage tool uptake, which could

challenge implementation. Clinician education and further evaluation is therefore required prior to national roll out to ensure standardised, cost-effective and evidence-based triage across trauma networks.

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Contributors GF conceived the study. All authors (GF, JB, EH, SK, JM, RP, JT, FL, AE, AR, TC, FB, MS, JS, GP, SR, MM, SW, CC and the MATTS research group) contributed to design the study. JB and GF performed the data management. JM and RP collected and coded the data. EH and GF performed the analyses. All authors (GF, JB, EH, SK, JM, RP, JT, FL, AE, AR, TC, FB, MS, JS, GP, SR, MM, SW, CC and the MATTS research group) made substantial contributions to data interpretation. GF drafted the article and all other authors revised it critically for important intellectual content. CC is the guarantor. All authors had full access to all the data in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis.

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ORCID iDs

Gordon Fuller <https://orcid.org/0000-0001-8532-3500>
 Joshua Miller <https://orcid.org/0000-0003-1990-4029>
 Richard Pilbery <https://orcid.org/0000-0002-5797-9788>
 Janette Turner <https://orcid.org/0000-0003-3884-7875>
 Andy Rosser <https://orcid.org/0000-0002-5477-4269>
 Fiona Bell <https://orcid.org/0000-0003-4503-1903>
 Michael Smyth <https://orcid.org/0000-0003-0220-2223>
 Jason E Smith <https://orcid.org/0000-0002-6143-0421>

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