Comparative analysis of major incident triage tools in children: a UK population-based analysis

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ABSTRACT

Introduction Triage is a key principle in the effective management of major incidents. There is currently a paucity of evidence to guide the triage of children. The aim of this study was to perform a comparative analysis of nine adult and paediatric triage tools, including the novel ‘Sheffield Paediatric Triage Tool’ (SPTT), assessing their ability in identifying patients needing life-saving interventions (LSIs).

Methods A 10-year (2008–2017) retrospective database review of the Trauma Audit Research Network (TARN) Database for paediatric patients (<16 years) was performed. Primary outcome was identification of patients receiving one or more LSIs from a previously defined list. Secondary outcomes included mortality and prediction of Injury Severity Score (ISS) >15. Primary analysis was conducted on patients with complete prehospital physiological data with planned secondary analyses using first recorded data. Performance characteristics were evaluated using sensitivity, specificity, undertriage and overtriage.

Results 15 133 patients met TARN inclusion criteria. 4962 (32.8%) had complete prehospital physiological data and 8255 (54.5%) had complete first recorded physiological data. The majority of patients were male (69.5%), with a median age of 11.9 years. The overwhelming majority of patients (95.4%) sustained blunt trauma, yielding a median ISS of 9 and overall, 875 patients (17.6%) received at least one LSI. The SPTT demonstrated the greatest sensitivity of all triage tools at identifying need for LSI (92.2%) but was associated with the highest rate of overtriage (75.0%). Both the Paediatric Triage Tape (sensitivity 34.1%) and JumpSTART (sensitivity 45.0%) performed less well at identifying LSI. By contrast, the adult Modified Physiological Triage Tool-24 (MPTT-24) score used in both civilian and military practice in adults.

Conclusion The SPTT and MPTT-24 outperform existing paediatric triage tools at identifying those patients requiring LSIs. This may necessitate a change in recommended practice. Further work is needed to determine the optimum method of paediatric major incident triage, but consideration should be given to simplifying major incident triage by the use of a single generic tool (the MPTT-24) for adults and children.

INTRODUCTION

Major incidents occur worldwide on a regular basis, when existing resources are outstripped due to the number, type, severity or location of casualties, necessitating additional support. Triage is a key principle in effectively managing major incidents, whereby patients are prioritised on the basis of their clinical acuity, typically using a simple physiological assessment as part of a triage tool. While existing triage tools have been derived and validated using mortality and injury severity as outcomes of interest, neither of these reflect the acuity of the patient or the need for a life-saving intervention.

In the UK, two paediatric major incident triage tools exist: the Paediatric Triage Tape (PTT) for prehospital use in patients under 12 years and JumpSTART (for in-hospital use in patients under
9 years) Both are paediatric adaptations of adult triage tools (Major Incident Medical Management and Support (MIMMS) Triage Sieve, and Simple Triage and Rapid Treatment (START), respectively) and use a stepwise approach to triage; the PTT uses physiological variables based on the child’s length as a proportionate surrogate for age, and JumpSTART uses a single respiratory rate threshold. Within the UK, one further alternative method of paediatric triage has been proposed. This is the Sheffield Paediatric Triage Tool (SPTT), a paediatric adaptation of the adult Modified Physiological Triage Tool-24 (MPTT-24) (online supplemental figure 1). The SPTT has undergone practical testing within a simulated paediatric major incident, where it correctly triaged all patients, thereby representing a potentially viable alternative to the PTT and JumpSTART (C O’Connell, personal communication, 25 January 2020).

Extensive research has been conducted in adult major incident triage, leading to the development and implementation of the MPTT-24 into both UK military pre-hospital and civilian in-hospital practice (NHS Clinical Guidelines for Major Incidents). By contrast, there is a paucity of evidence surrounding paediatric major incident triage tools. Limited studies have evaluated the performance of existing triage tools in identifying the need for life-saving interventions, and these have demonstrated poor performance of existing UK methods. Perhaps the greatest challenge in designing a fit-for-purpose paediatric major incident tool is the determination of appropriate physiological thresholds denoting the need for intervention. Normal ranges are wide and change with age, leading to potential for confusion in those performing triage in this high stakes, high stress event.

Ideally, any study examining the performance of triage tools should be tested in the environment in which they are to be used, (ie, within the major incident context). However, due to the unpredictability of major incidents and associated ethical implications, the feasibility of such an assessment is very low. As a result, trauma registries, which contain high numbers of seriously injured patients, are often used as a proxy to examine the performance accuracy of such triage tools. By contrast, there is a paucity of evidence surrounding paediatric patients (defined as under 16 years) with subgroup analyses conducted for the age ranges <1 year, 1–2 years, 2–5 years, 5–12 years, 12–16 years, <12 years, <16 years.

The aim of this study was to compare the performance of the MPTT-24 and its paediatric derivative, the SPTT with existing adult and paediatric triage tools using the UK Trauma Audit and Research Network (TARN) Database. The primary outcome was their performance accuracy in identifying paediatric patients in need of a life-saving intervention (priority one patients). Patients receiving one or more life-saving interventions based on a previously defined list (with adaptations for paediatric fluid resuscitation in keeping with APLS) were considered to be priority one (online supplemental table 1).

Primary analysis for all outcomes of interest was conducted on patients with complete prehospital physiological data. A planned secondary analysis was conducted using first recorded physiological data, whether performed in the prehospital or ED setting. Patients were categorised as priority one, or not priority one, using available paediatric (PTT, JumpSTART and SPTT) and adult (MPTT-24 (including airway opening manoeuvre), Careflight, MIMMS Triage Sieve, Rapid Assessment of Mentation and Pulse (RAMP)) triage tools. In keeping with the design of the JumpSTART and PTT, once a patient reached a predefined age (8 and 12 years, respectively), they were then triaged by the corresponding adult triage tool (START and MIMMS Triage Sieve, respectively). A comparison of the different triage tools is shown in table 1. Assumptions made for the categorisation of triage tools are described in online supplemental file 2.

The primary outcome was the correct determination of priority one status (requirement for life-saving intervention) in paediatric patients (defined as under 16 years) with subgroup analyses conducted for the age ranges <1 year, 1–2 years, 2–5 years, 5–12 years, 12–16 years, <12 years, <16 years.

Secondary outcome measures included the prediction of major trauma (defined as Injury Severity Score (ISS) >15) and mortality.

Missing data
A comparison was made between patients with complete data and those missing prehospital physiological data, to explore for systematic differences in ISS, mortality and need for life-saving intervention. Performing a list-wise deletion on patients without complete data can introduce systematic errors, therefore multiple imputation was used on the first recorded physiological data set in order to derive imputed data. Details of the modelling strategy are provided in online supplemental file 3. In keeping with the main methods, a comparative analysis was then performed on the imputed data set.

Statistical analysis
Statistical analysis was performed to derive the sensitivity and specificity of the triage tools in detecting the outcomes of interest. Undertriage and overtriage were calculated in keeping with previously published methods on trauma triage (1-sensitivity and 1-positive predictive value). A X² test was used to evaluate for statistical significance in categorical variables between included and excluded groups. Data distribution between the first recorded physiology group and the imputed data group was compared using a Kolmogorov-Smirnov test. Python software (V3.7, Scotts Valley California, 2009) and R software (V3.6, R Core Team, New Zealand, 2000) were used for data processing and analysis.

Patient and public involvement
Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

RESULTS
During the study period, 15 133 patients aged under 16 years met TARN inclusion criteria, of which 4962 (32.8%) had complete prehospital physiological data and 8255 (54.5%) had complete first recorded physiological data (at scene and ED). A study flow
Median age was 11.9 years (IQR 8.0–14.2), and the majority of patients were male (69.5%). Median ISS was 9 (IQR 6–14). Blunt trauma predominated (95.4%), with motor vehicle collisions (49.6%) and low falls (23.9%) the leading mechanisms of injury. In total, 875 (17.6%) of patients with complete prehospital physiological data received at priority one status (92.2%, 95% CI 90.5% to 93.7%), followed by the MPTT-24 (80.8%, 95% CI 78.4% to 83.0%). The performance of the SPTT represents an absolute increase in sensitivity (7.8% and 19.2%, respectively, for the SPTT and MPTT-24), but corresponding to specificities of 12.1% and 39.6%, respectively. Full test characteristics (including overtriage and undertriage rates) of all triage tools in the primary analysis are shown in table 4A with summary results shown in online supplemental table 2. For detecting major trauma, the SPTT demonstrated the highest sensitivity (91.8%, 95% CI 90.3% to 93.1%) followed by the MPTT-24 (75.6%, 95% CI 73.5% to 77.7%), with both PTT and JumpSTART demonstrating much lower sensitivity (28.8%, 95% CI 26.6% to 31.0%; and 36.0%, 95% CI 33.7% to 38.4%, respectively). For mortality, the SPTT, MPTT-24 and JumpSTART all had comparable sensitivities (83.0%–88.7%), outperforming the PTT (71.7%, 95% CI 57.7% to 83.2%). The full test characteristics for the secondary outcomes are provided in table 4B,C.

### Subgroup analysis by age category
The SPTT demonstrated a high sensitivity across all age groups (89.3%–96.3%), with its lowest in the 5–12 years age group. The performance of PTT reduced as age increased, exhibiting the lowest sensitivity (20.8%, 95% CI 14.8% to 28.4%) for the younger children (0–4 years).

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**Table 1 Triage tool comparison**

| Tool | Tool components |
|------|-----------------|
| **Paediatric Triage Tape (PTT)** | <10 kg: alert and moving all limbs or walking >19 kg: walking |
| **JumpSTART** | Walking? Breathing (open airway if required) If apnoeic, assess for pulse. If present, give 5 rescue breaths. |
| **Sheffield Paediatric Triage Tool (SPTT)** | Catastrophic haemorrhage? Walking? Breathing (open airway if required) If apnoeic, assess for pulse. If present, give 5 rescue breaths. |
| **Careflight** | Walking?obeys commands? Palpable radial pulse? OR Breaths with open airway? |
| **Major Incident Medical Management and Support (MIMMS) Triage Sieve** | Walking? Breathing (open airway if required) If apnoeic, assess for pulse. If present, give 5 rescue breaths. |
| **Modified Physiological Triage Tool 24 (MPTT-24)** | Catastrophic haemorrhage? Walking? Breathing (open airway if required) |
| **Modified Simple Triage and Rapid Treatment** | Walking? Spontaneous breathing |
| **National Ambulance Service Medical Directors (NASMed) Triage Sieve** | Catastrophic haemorrhage? Are they injured? Walking? |
| **Rapid Assessment of Mentation and Pulse (RAMP)** | Casualty without signs of obvious death Casualty follows commands |

*R: <1: 30–40, 1–2: 25–25, 2–5: 20–25, 5–12: 20–30, >12: 15–20. HR: <1: 110–160, 1–2: 100–150, 2–5: 95–140, 5–12: 90–120, >12: 60–100.

|MPTT-24 was updated in 2018 following consultation with NHS England to explicitly include the ‘open airway’ step as part of the breathing assessment. This current version is currently in use in both UK military and civilian in-hospital practice (within the NHS Clinical Guidelines for Major Incidents).§AVPU: Alert, responds to Voice, responds to Pain, Unconscious.

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**Figure 1** Triage triage tool comparison diagram is shown in figure 1 with age group breakdown detailed in table 2. Median age was 11.9 years (IQR 8.0–14.2), and the majority of patients were male (69.5%). Median ISS was 9 (IQR 9–17) with low overall mortality (1.1%). Blunt trauma predominated (95.4%), with motor vehicle collisions (49.6%) and low falls (23.9%) the leading mechanisms of injury. In total, 875 (17.6%) of patients with complete prehospital physiological data received at priority one status (92.2%, 95% CI 90.5% to 93.7%), followed by the MPTT-24 (80.8%, 95% CI 78.4% to 83.0%). The performance of the SPTT represents an absolute increase in sensitivity (7.8% and 19.2%, respectively, for the SPTT and MPTT-24), but corresponding to specificities of 12.1% and 39.6%, respectively. Full test characteristics (including overtriage and undertriage rates) of all triage tools in the primary analysis are shown in table 4A with summary results shown in online supplemental table 2. For detecting major trauma, the SPTT demonstrated the highest sensitivity (91.8%, 95% CI 90.3% to 93.1%) followed by the MPTT-24 (75.6%, 95% CI 73.5% to 77.7%), with both PTT and JumpSTART demonstrating much lower sensitivity (28.8%, 95% CI 26.6% to 31.0%; and 36.0%, 95% CI 33.7% to 38.4%, respectively). For mortality, the SPTT, MPTT-24 and JumpSTART all had comparable sensitivities (83.0%–88.7%), outperforming the PTT (71.7%, 95% CI 57.7% to 83.2%). The full test characteristics for the secondary outcomes are provided in table 4B,C.
12–16 years age group. By contrast, the performance of Jump-START varied between the age groups and did not demonstrate a consistent trend. In the oldest age group (12–16 years), the MPTT-24 demonstrated the greatest sensitivity (98.0%, 95% CI 93.8% to 99.5%) and apart from the SPTT, the remaining paediatric triage tools showed the worst performance across all age groups against which they were assessed. This subgroup analysis is provided in detail in online supplemental table 3.

Secondary analysis
First recorded physiological data (including prehospital and ED) were available for 8255 patients (54.5%). Within this cohort, the median age was 10.4 years (IQR 5.2–13.7) with men continuing to account for the majority of cases (68.7%). The outcome and median ISS remained unchanged (1.1% mortality, median ISS 9 (IQR 9–17)) to the primary analysis. A comparable proportion (16.3 vs 17.6%) received at least one life-saving intervention, with advanced airway intervention again predominating (60.1%).

Tool performance was largely similar to the primary analysis, with the SPTT exhibiting the highest sensitivity (90.0%, 95% CI 88.5% to 91.2%), followed by the MPTT-24 (81.2%, 95% CI 79.5% to 82.9%). The full secondary analysis test characteristics are provided in online supplemental table 4.

Missing data
A significant proportion of patients had incomplete prehospital physiological data (n=10 171, 67.2%). Those with missing data were significantly younger (median age 3.9 vs 11.9, p<0.0001). While no difference was observed in median ISS, the outcome differed between the two groups with a higher mortality in those excluded (3.1% vs 1.1%, p<0.0001). Additionally, the leading mechanisms of injury were ‘reversed’ between the complete (motor vehicle collision 49.6%, low falls 23.9%) and incomplete data groups (motor vehicle collision 22.2%, low falls 47.5%).

Performance characteristics were unchanged following multiple imputation to account for missing data. The full test characteristics are provided in online supplemental table 4b,c.

DISCUSSION
Using a large civilian trauma registry, we have validated the performance accuracy of the novel SPTT and compared it with existing adult and paediatric triage tools in identifying the need for life-saving interventions in a UK paediatric population. The SPTT (a specific paediatric tool) and the MPTT-24 (an adult triage tool) are the most accurate at predicting need for life-saving intervention, major injury and mortality in the paediatric population.

While there has been much recent focus on defining the optimal major incident triage tool for adult patients, this has not yet been the case for children. Few bespoke paediatric triage tools have been derived and there are minimal data from external validations to support the use of one over another on the basis of performance characteristics.2 15 23–25 While previous studies have compared triage tool performance using either mortality or ISS, neither of these are likely to extrapolate well to the acuity of the patient while in the prehospital setting.2–4 In a major incident, the purpose of triage is to prioritise those patients who may benefit from life-saving interventions.2 5 26 This outcome measure should therefore form the primary outcome of interest in the assessment of any such tool. The performance accuracy of the triage tools assessed in this study was further delineated using subgroup analysis by age range, and extended to the secondary outcomes of major trauma and mortality.

The first paediatric tool, PTT,6 was developed to prevent over-triage when the adult Triage Sieve was used on paediatric patients. In a previous comparative analysis, PTT showed high specificity (>98%) for identifying patients who either required life-saving interventions or who had sustained major trauma (ISS >15). However, despite good specificity, the tool demonstrated poor sensitivity for both outcomes, corresponding to undertriage rates in excess of 58%.2 In the same study, JumpSTART, while also

![Figure 1](https://via.placeholder.com/150)

**Figure 1** Study flow diagram.

### Table 2 Age group breakdown and data completeness

| Age         | Under 1 | 1–2 years | 2–5 years | 5–12 years | 12–16 years |
|-------------|---------|-----------|-----------|------------|-------------|
| Frequency (n (%)) | 2072 (13.7) | 1261 (8.3) | 3045 (20.1) | 4572 (30.2) | 4183 (27.6) |
| Complete prehospital physiology (n (%)) | 145 (2.9) | 59 (1.2) | 445 (9.0) | 1915 (38.6) | 2398 (48.3) |
| Complete first available physiology (n (%)) | 508 (24.5) | 260 (20.6) | 1093 (35.9) | 3095 (67.7) | 3299 (78.9) |
| Complete first available physiology (n (%)) | 1178 (56.7) | 675 (53.5) | 2044 (67.1) | 3755 (82.1) | 3631 (86.8) |

*Overall study population age <16 years, n=15 133.
†Complete first available physiological data (ED and prehospital physiological data).
‡Complete first available physiological data (ED and prehospital physiological using imputed data.)
performing with high specificity (>97%), demonstrated less than 5% sensitivity for both outcomes, correlating with undertriage rates in excess of 95%. A further study used trauma registry data to assess performance accuracy of triage tools in predicting mortality and major trauma, and reported similar sensitivity levels for the PTT but considerably lower specificity (66.0% and 66.5%, respectively). By contrast, JumpSTART demonstrated better performance. With life-saving intervention being our primary outcome measure, our study aligns more closely to the former study, and while we report life-saving intervention being our primary outcome measure, our in-surge situations within hospital settings.

Table 3  Characteristics of study population

| Variable                   | Complete population (n=15 133) | Complete prehospital data (n=4962, 32.8%) | Complete first available data (n=8255, 54.5%) |
|----------------------------|--------------------------------|--------------------------------------------|----------------------------------------------|
| Gender                     | Male                           | 10 294 (68.0%)                            | 3447 (69.5%)                                 | 5682 (68.8%)                                |
|                           | Female                         | 4839 (32.0%)                              | 1515 (30.5%)                                 | 2573 (31.2%)                                |
| Injury Severity Score (median (IQR)) | 9 (9–16)                      | 9 (9–17)                                  | 9 (9–16)                                     |
| Age (years) (median (IQR))  | 7 (2.3–12.5)                   | 11.9 (8–14.2)                             | 10.7 (5.6–13.8)                              |
| Outcome                    | Alive                          | 14 764 (97.6%)                            | 4909 (98.9%)                                 | 8188 (99.2%)                                |
|                           | Dead                           | 369 (2.4%)                                | 53 (1.1%)                                    | 67 (0.8%)                                   |
| Mode of injury             | Blunt                          | 14 668 (96.9%)                            | 4733 (95.4%)                                 | 7912 (95.8%)                                |
|                           | Penetrating                    | 465 (3.1%)                                | 229 (4.6%)                                   | 343 (4.2%)                                  |
| Mechanism of injury (n (%)) | Fall less than 2 m             | 6014 (39.7)                               | 1187 (23.9)                                  | 2374 (28.8)                                 |
|                           | Vehicle incident/collision     | 4721 (31.2%)                              | 2459 (49.6)                                  | 3616 (43.8)                                 |
|                           | Fall more than 2 m             | 1514 (10.0)                               | 645 (13.0)                                   | 1031 (12.5)                                 |
|                           | Blow(s)                        | 1270 (8.4)                                | 327 (6.6)                                    | 601 (7.3)                                   |
|                           | Other                          | 1118 (7.4)                                | 147 (3.0)                                    | 319 (3.9)                                   |
|                           | Stabbing                       | 229 (1.5)                                 | 130 (2.6)                                    | 196 (2.4)                                   |
|                           | Crush                          | 160 (1.1)                                 | 42 (0.9)                                     | 73 (0.9)                                    |
|                           | Burn                           | 44 (0.3)                                  | 4 (0.1)                                      | 12 (0.2)                                    |
|                           | Shooting                       | 42 (0.3)                                  | 16 (0.3)                                     | 24 (0.3)                                    |
|                           | Blast                          | 21 (0.1)                                  | 5 (0.1)                                      | 9 (0.1)                                     |
| Priority one (n (%))       | 2820 (18.6)                   | 875 (17.6)                                | 1349 (16.3)                                  |

The key principles of triage are that it should be rapid, reliable and reproducible, irrespective of the provider performing it. The reliability of the triage tool is the assessment of its performance; key to which is identifying those in need of life-saving interventions and minimising undertriage (the misclassification of patients as not needing a life-saving intervention). An ideal setting, the triage tool used would minimise both undertriage and overtriage, but the reality is that increasing sensitivity often corresponds to decreasing specificity necessitating a decision over their importance. An additional factor, when assessing triage methods, lies with their application simplicity; an overly complex triage system with good performance may not be practical, particularly within prehospital settings. While the SPTT demonstrated the highest overall sensitivity in our study, the inclusion criteria will likely skew the study population towards those with more severe injuries. Therefore, it would be anticipated that the frequency of patients not receiving a life-saving intervention in the population will be higher than observed in this study.

Specific paediatric tools also differ in the ages in which the tools are recommended (JumpSTART and the PTT differ in their approach, recommending cut-offs at 8 and 12 years, respectively). For example, the subgroup analysis of the 12–16 years age group in this study demonstrates directly comparable median physiological parameters with that observed in a previous adult major incident triage study, which would support the approach taken by the PTT.

One potential solution is the application of a single tool across all age ranges, covering adult and paediatric patients. This may need to involve a compromise between optimal tool performance, practicality and ease of use. The adoption of single physiological thresholds, such as those used in the MPTT-24,9 represents a more simplistic option and will convey additional benefit from the perspective of familiarity and training. However, as observed within the MPTT-24 performance analysis, while this reduces undertriage, it is associated with increased overtriage, although comparable with that tolerated within the adult setting.

Limitations

A key limitation of our work lies with the use of a retrospective trauma database. First, the mechanism of injury encountered on the database (road traffic collisions and low falls) is unlikely to accurately represent the injury pattern encountered following a major incident in its totality. Ideally, any analysis of triage tools should be performed in the environment in which they are designed to function but owing to the unpredictable nature of major incidents, this is both impractical and also largely unethical as well as unrealistic given the frequency of paediatric major incidents. As a result, trauma databases are frequently used as a surrogate, allowing for the analysis of a large number of seriously injured patients. A further limitation is the presence of inclusion criteria for entry into the TARN database; while only a minority of patients (17.6%) received a life-saving intervention in our analysis, the inclusion criteria will likely skew the study population towards those with more severe injuries. Therefore, it would be anticipated that the frequency of patients not receiving a life-saving intervention in the population will be higher than observed in this study.

We also acknowledge that the exclusion of patients with incomplete physiological data is an additional limitation of our study, with only 32.8% having complete prehospital data with which to perform the primary analysis. While median ISS is comparable between the included and excluded groups, we did observe a difference in median age and outcome, with those patients in the excluded group being younger and having a higher mortality. In an attempt to mitigate for the missing prehospital data, additional analyses were conducted using first recorded physiological data (including ED data) and also on an imputed data set. However, even this is imperfect as physiology may have changed by arrival to ED in response to any interventions.
performed in the prehospital setting. Performance characteristics of the triage tools were unchanged in these further analyses.

CONCLUSION
In this comparative analysis of paediatric triage tools, the SPTT and MPTT-24 perform better than existing paediatric triage tools for identifying those patients requiring life-saving intervention. This may necessitate a change in recommended practice. Further work is required to determine the optimum method of paediatric major incident triage, but consideration should be given to simplifying major incident triage systems in a pediatric population.

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