ORIGINAL RESEARCH

Independent Application of the Sacco Disaster Triage Method to Pediatric Trauma Patients

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Abbreviations:
AUC: area under the receiver-operator curve
GCS: Glasgow Coma Scale
NTDB: National Trauma Data Base
ROC: receiver-operator curve
STM: Sacco Triage Method

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Abstract

Introduction: Though many mass-casualty triage methods have been proposed, few have been validated in an evidence-based manner. The Sacco Triage Method (STM) has been shown to accurately stratify adult victims of blunt and penetrating trauma into groups of increasing mortality risk. However, it has not been validated for pediatric trauma victims.

Purpose: Evaluate the STM's performance in pediatric trauma victims.

Methods: Records from the United States' National Trauma Data Base, a registry of trauma victims developed by the American College of Surgeons, were extracted for the 2007-2009 reporting years. Patients ≤18 years of age transported from a trauma scene with complete initial scene data were included in the analysis. Sacco triage scores were assigned to each registry patient, and receiver-operator curves were developed for predicting mortality, along with several secondary outcomes. Area under the receiver-operator curve (AUC) was the main outcome statistic. Sensitivity analysis was performed using a Sacco score without age adjustment, using blunt versus penetrating trauma, and using patients <12 years of age.

Results: There were 210,175 pediatric records, of which 90,037 had complete data for analysis. The STM with age adjustment predicted pediatric trauma mortality with an AUC of 0.933 (95% CI: 0.925-0.940). Without the age adjustment term, it predicted mortality with an AUC of 0.924 (95% CI: 0.916-0.933). The STM with age adjustment predicted blunt trauma mortality in 72,467 patients with an AUC of 0.938 (95% CI: 0.929-0.947) and penetrating trauma mortality in 10,099 patients with an AUC of 0.927 (95% CI: 0.911-0.943). These findings did not change significantly when analysis was limited to patients <12 years of age. The Sacco Triage Method was also predictive of some secondary outcomes, such as major injury and death on arrival to the emergency department.

Conclusion: The Sacco Triage Method, with or without its age adjustment term, was a highly accurate predictor of mortality in pediatric trauma patients in this registry database. This triage method appears to be a valid strategy for the prioritization of injured children.

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Introduction

A key task in any mass-casualty incident is the rapid and accurate sorting of victims with life-threatening injuries from those without. A variety of triage methods have been proposed—and used—in the two centuries since Napoleonic-era doctors first started large-scale sorting of battlefield casualties. Various groups of experts have developed, refined, and promoted triage methodologies such as Simple Triage and Rapid Transport (START), Careflight, Secondary Assessment of Victim Endpoint (SAVE) and others.[1-4]

A criticism of most mass-casualty triage methods is their lack of rigorous evidence basis, often combined with less-than-ideal evaluations of their real-world performance.[5-9] One effort to move beyond expert opinion in the development of mass-casualty triage is the Sacco Triage Method (STM), eponymously named for the lead developer, Dr. William Sacco. He and his colleagues used large trauma registries in Pennsylvania to perform evidence-based validation of their triage system's ability to stratify each victim's mortality risk based on respirations, pulse, and motor response. For adult patients with either blunt[10] or penetrating[11] trauma, STM effectively sorts patients into groups by risk of death.

However, STM has not been widely used or assessed in real-world settings, nor has it been validated for accuracy in burn patients, victims of chemical or radiological exposure, or pediatric casualties. The published validation studies noted above were performed by the same investigators who proposed the method, rather than by an independent group.

In this study, the objective was to independently test the STM as proposed by Sacco et al against a large number of pediatric trauma patients in order to determine its validity as a triage method for children.

Methods

Subjects

The patient population for this study comes from the de-identified National Trauma Data Base (NTDB Version 7.2 Chicago, Illinois USA), which is collected from participating trauma centers around the United States. It is managed by the Committee on Trauma of the American College of Surgeons. The content reproduced from the NTDB remains the full and exclusive copyrighted property of the American College of Surgeons. The American College of Surgeons is not responsible for any claims arising from works based on the original data, text, tables, or figures.

This registry gathers approximately 600,000 trauma records per year, roughly 20% of which represent pediatric patients. NTDB records are subject to the a priori inclusion, exclusion, and validation rules stated by the registry, as described at www.facs.org/trauma/ntdb/ntdbapp.html. The institutional review board for the authors' institutions found this study to be exempt from formal review, as the NTDB data are pre-existing and de-identified.

From the NTDB registry, this study included all patients from 2007, 2008 and 2009 with a recorded age from 0 to 18 years, 364 days. A portion of the NTDB records represent inter-facility transfers (rather than transport from a trauma scene to a hospital)—these records were excluded. The study also excluded any record found to have an emergency department length of stay (LOS) either >7 days or greater than the total recorded hospital LOS, because these records likely represented data entry errors or highly unusual trauma care. This process yielded 210,175 pediatric scene-to-hospital trauma registry records for study analysis.

Triage Assignment

The Sacco Triage Method assigns a triage score to each patient based on four factors: respirations, pulse, motor response and age. This study followed the Sacco Triage Method as shown in Table 1 to assign subscores for each factor.

For motor response, the study used the recorded score for the motor component of the patient's initial Glasgow Coma Scale (GCS) in this manner:

- GCS-Motor = 6 → Sacco Motor Response subscore = 4
- GCS-Motor = 5 → Sacco Motor Response subscore = 3
- GCS-Motor = 4 → Sacco Motor Response subscore = 2
- GCS-Motor = 2 or 3 → Sacco Motor Response subscore = 1
- GCS-Motor = 1 → Sacco Motor Response subscore = 0.

The total Sacco Triage Score for each patient was the sum of the four factor subscores. Not all records had complete initial (scene) information for respiration, pulse, and GCS-motor. Therefore only a subset of records could be assigned pre-hospital Sacco Scores. These scores range from 0 to 14 in children. A higher Sacco Score indicates a healthier patient.

The study also assigned each record an "unadjusted" Sacco Score by omitting the age adjustment subscore from the total. Presumably, this unadjusted Sacco Score is less physiologically accurate, but easier for scene responders to calculate. It is also the score used in two published papers validating the STM in adults.[10,11] Unadjusted Sacco Scores range from 0 to 12.

Outcomes

The primary outcome was patient ***mortality***. Mortality was defined as death before hospital discharge as recorded in the NTDB registry's hospital disposition information. The study assessed several secondary patient outcomes: death on arrival; major injury; serious outcome; and admission to hospital. ***Death on arrival*** was defined as having a recorded emergency department disposition of "death" regardless of duration of resuscitation efforts. ***Major injury*** was defined as having a recorded Injury Severity Score greater than 15.[12] ***Serious outcome*** was defined as the combined endpoint that included all deaths, all transfers for acute care, all admissions to the intensive care unit or operating room, and any ward admission lasting more than two days. ***Admission*** was disposition from the emergency department to any hospital inpatient service.

Analysis

Data were transferred from the NTDB into SPSS version 20 (IBM, Armonk, New York USA) for cleaning and statistical analysis. Cleaning involved application of the above inclusion and exclusion rules, the assignment of Sacco Scores, and coding the outcome endpoints. Analysis consisted of development of basic demographic and statistical tables, and receiver-operator curve (ROC) analysis using SPSS tools. Graphs were created with Microsoft Excel 2010 (Redmond, Washington USA).

The study evaluated the accuracy of the Sacco Score for predicting primary and secondary outcomes, as illustrated in the ROC and quantified by the area under the curve (AUC). These results are reported with confidence intervals.

Sensitivity analysis was performed using different calculation methods: the "regular" Sacco Score and the "unadjusted" Sacco Score. It was also performed using different trauma patient subsets: all traumas vs. blunt trauma vs. penetrating trauma vs. burn patients. Finally, because the Sacco Score was originally developed for adults and its accuracy in younger children may be different from its accuracy in more adult-like teenagers, sensitivity analysis was performed using all pediatric patients (including teenagers) versus using only children age 0 to 11 years.

Results

The study data set included 210,175 records with 5,218 deaths. Of these records, 90,037, including 1,538 deaths, had complete data for Sacco Scoring. Characteristics of the patients represented in the records are shown in Table 2.

Prediction of Primary Outcome—Mortality

The mortality rate for each level of Sacco Score is shown in Table 3. Note that no patients had a Sacco Score of 0, and only two patients had a score of 1. With the exception of Sacco Score = 1 (which had 1 death and 1 survivor), there were steadily decreasing mortality rates seen with increasing Sacco Scores. The most deaths occurred among patients with Sacco Scores of 5, 7, 8, and 9 (each with more than 150 deaths), albeit at steadily lower rates.

The ROC for predicting mortality with initial scene Sacco Triage Score is shown in Figure 1. The area under the curve is 0.933 (95% CI: 0.925-0.940).

Predicting Secondary Outcomes

The STM was predictive of several secondary outcomes. Table 4 summarizes the AUC findings for predicting death on arrival, major injury, any serious outcome, and any admission.

Sacco SubScore →	-2	-1	0	1	2	3	4
Respirations per minute	-	-	0	1-9	36+	25-35	10-24
Heartbeat per minute	-	-	0	1-40	41-60	121+	61-120
Motor Response	-	-	No Response	Extension or Flexion	Withdraws	Localizes	Obeys Commands
Adjustment for Age in years	75+	55-74	15-54	8-14	0-8	-	-

Table 1. Sacco Triage Method Scoring Grid. For each row (factor), a subscore is assigned. This study included only pediatric patients, so the negative values for the age adjustment subscore were not applicable and the sum of the subscores gives a total Sacco Score of 0 to 14. Excluding the age adjustment gives an "unadjusted" Sacco Score of 0 to 12.

	All Scene Transports Ages 0-18 in Database	All Scene Transports Ages 0-18 with Complete Data for Sacco Scoring	All Scene Transports Ages 0-11 with Complete Data for Sacco Scoring
Number of patient records	210,175	90,037	28,619
Age in years, mean (SD)	11.1 (6.0)	12.7 (5.4)	5.6 (3.5)
Gender Data Present, n (%)	208,490 (99.2)	89,438 (99.3)	28,465 (99.5)
Male Gender, n (%)	140,048 (67.2)	60,347 (67.5)	18,001 (62.9)
Injury Severity Score Present, n (%)	197,456 (93.9)	86,743 (96.3)	27,579 (96.4)
Injury Severity Score, mean (SD)	8.6 (9.1)	9.4 (9.2)	8.2 (8.0)
Mortality Data Present, n (%)	204,223 (97.2)	87,731 (97.4)	27,805 (97.2)
Deaths, n (%)	5,218 (2.5)	1,538 (1.7)	350 (1.2)
Race Data Present, n (%)	188,788 (89.4)	80,866 (89.8)	25,098 (87.7)
Nonwhite Race, n (%)	113,530 (54.0)	48,139 (53.5)	10,889 (38.0)
Payer Data Present, n (%)	175,820 (83.7)	76,023 (84.4)	24,827 (86.8)
Government Payer, n (%)	56,839 (27.0)	23,279 (25.6)	10,144 (35.4)

Table 2. Records in the Study Dataset with Basic Demographic Information, and the Completeness of Data Fields of Interest. All percentages shown use the top row number of patients for each column as the denominator.

Also shown is the performance of the "unadjusted" Sacco Score for each outcome of interest.

Sensitivity Analysis by Penetrating vs. Blunt Trauma

There were 72,467 pediatric blunt trauma patients with complete data for analysis. Mortality outcomes by Sacco Score for these patients are shown in Table 3. The resulting ROC for blunt trauma is shown in Figure 1. This ROC has an area under the curve of 0.938 (95% CI: 0.929-0.947).

There were 10,099 pediatric penetrating trauma patients with complete data for analysis. Mortality outcomes by Sacco Score for pediatric penetrating trauma patients are shown in Table 3. The resulting ROC for penetrating trauma is shown in Figure 1. This ROC has an area under the curve of 0.927 (95% CI: 0.911-0.943).

Remaining patients in the data set had either missing data for trauma type (n = 5,542), or were burn patients (n = 1,711). There were too few burn patient records for a useful analysis when segmented by mortality outcome and Sacco Score.

Sensitivity Analysis of Younger Children

Children aged 12 or older may be physiologically similar to adults, while younger children may not be. The STM may perform better when all pediatric trauma patients are analyzed because many of the patients in the database are teenagers. To assess this possibility, a sensitivity analysis was performed by evaluating results for primary and secondary outcomes in children aged 0 to 11 years. There were 28,619 such patients, including 350 deaths, with complete data for analysis. The demographic breakdown of this

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Sacco Score	All Trauma Mortality		Blunt Trauma Mortality		Penetrating Trauma Mortality	
	Deaths/Total	Percent	Deaths/Total	Percent	Deaths/Total	Percent
1	1/2	50	0/0	NM	1/2	50
2	13/19	68	5/10	50	7/8	88
3	57/85	67	24/49	49	28/30	93
4	146/273	53.5	103/220	46.8	40/48	83
5	185/387	47.8	122/302	40.4	53/67	79
6	144/396	36.4	103/305	33.8	31/53	59
7	175/692	25.3	125/573	21.8	38/64	59
8	298/1591	18.7	206/1354	15.2	77/135	57
9	162/1772	9.1	102/1474	6.9	47/180	26.1
10	120/3941	3.0	67/3281	2.0	36/420	8.6
11	115/8478	1.4	61/6696	0.9	45/1219	3.7
12	95/42166	0.2	53/33621	0.2	36/6570	0.5
13	23/22412	0.1	16/19736	0.1	4/1112	0.4
14	4/5508	0.1	2/4846	0.0	0/191	0.0
Total	1538/87631	1.8	989/72467	1.4	443/10099	4.4

Table 3. Mortality by Sacco Score. Note that no patients had a score of 0, and only two patients had a score of 1. NM indicates division by zero for a percentage, a result with no meaning. Patients counted in the "All Trauma" column but not appearing in either the "Blunt Trauma" or "Penetrating Trauma" columns had either "Burns" or no trauma type recorded.

subset of younger patients appears in Table 2. The AUC results for Sacco Score and for unadjusted Sacco Score in this age group appear in Table 4 (lower section). They do not differ significantly from the results presented above for all pediatric patients.

Comparison with Published Adult Findings

The results for predicting mortality with unadjusted Sacco Scores are depicted graphically in Figure 2. The pediatric data are broken into penetrating and blunt trauma, as were the data in the adult source articles.[10,11] For all blunt trauma, and most penetrating trauma, observed mortality rates were lower in pediatric than in adult patients. The exception occurs among children with penetrating trauma and unadjusted Sacco Scores of 7, 8 and 9.

Discussion

Findings and Implications

This study showed the Sacco Triage Method, when applied to a large trauma registry database, is highly predictive of mortality risk in pediatric trauma patients. It accurately risk-stratifies pediatric trauma patients regardless of blunt versus penetrating trauma, in younger and older children alike, with high accuracy. Furthermore, this study's results suggest that for children the age adjustment term adds little to the predictive accuracy of the basic Sacco Score, which simply assesses respirations, pulse, and motor response. The usefulness of age adjustment for elderly trauma victims was not assessed.

While the accuracy of the STM for mortality prediction was high in this data set, the STM was not as reliable at predicting secondary outcomes. As shown in Table 4, the AUC ~0.5 for predicting any admission and the AUC ~0.6 for any serious outcome suggest far lower accuracy. The AUC ~0.7 for major injury was an intermediate result.

This study's results are similar to those previously published by Dr. Sacco and his colleagues for adult blunt and penetrating trauma patients.[10,11] The main difference is that the mortality at any given Sacco Score is typically lower for children than has been documented in adults. Both the adult studies, like the current pediatric study, used large trauma databases to perform validation. All are subject to similar limitations of validation against a retrospective, albeit large, registry database.

One criticism of the STM is its relative complexity. It assigns scores of 0 to 14 (or possibly -2 to 14 when pediatric and elderly patients are triaged together), resulting in over a dozen different "risk strata" compared to four strata (e.g. Red/Yellow/Green/Black) seen in other mass-casualty triage methods like START.[3] It may be possible to simplify the STM, at least with regard to pediatric victims. For example, the age adjustment subscore may represent added complexity that does not improve accuracy or outcomes. Scoring the remaining factors—respirations, pulse and motor response—in five levels (scores of 0 to 4) might also be simplified to two or three levels without loss of accuracy. Such an approach, if it can be validated, may allow placement of

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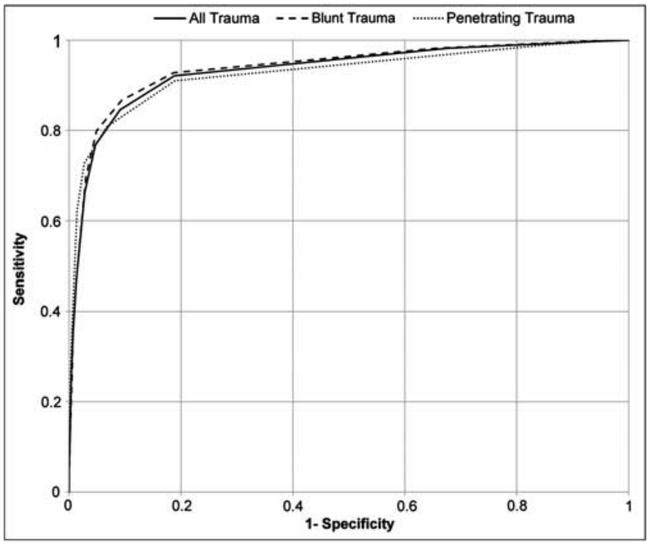

Figure 1. Mortality Receiver-Operator Curves (ROCs) for Sacco Triage Method by Trauma Type Receiver-operator curve for predicting initial mortality in pediatric trauma patients by Sacco Score. The area under the curve for all trauma combined is 0.933 (95% CI: 0.925-0.940). The blunt trauma ROC has an area under the curve of 0.938 (95% CI: 0.929-0.947). The penetrating trauma ROC has an area under the curve of 0.927 (95% CI: 0.911-0.943).

pediatric mass-casualty victims into simpler groupings akin to the traditional and familiar Red/Yellow/Green/Black assignments used in many other triage systems.

Limitations

This study is principally limited by its reliance on retrospective patient data reported to a national registry. Such data are clearly subject to data entry errors and misreporting. They are also prone to selection and reporting bias. Local trauma centers may have variations in their definitions of terms, despite the work of the American College of Surgeons and the National Trauma Data Base staff to promote common definitions, and consistent inclusion and exclusion criteria.

The generalizability of the data may be a second limitation of the study. The data set has a higher percentage of patients with serious illness and major injuries than is seen in most emergency departments because the data come from major trauma centers. A typical mass-casualty incident (if one can be "typical") may have significantly more patients with minor injuries, the so-called "walking wounded." These patients may be under-represented in this analysis. However, in most incidents the key function of a disaster triage method is identification of the more seriously ill and injured patients at high risk for mortality. Therefore, the fact that this registry data is enriched with sicker-than-average patients and numerous deaths makes it helpful for analyzing the STM predictive accuracy in the most urgent cases.

The age mix of a mass-casualty incident may also vary greatly, and this dataset is enriched with older children. To examine the impact of this limitation, this study presents a sensitivity analysis

Outcome of Interest for Ages 0 to 18 years	AUC for Sacco Score (95% CI)	AUC for Unadjusted Sacco Score (95% CI)
Mortality	0.933 (0.925-0.940)	0.924 (0.916-0.933)
Death on Arrival	0.897 (0.869-0.925)	0.903 (0.877-0.929)
Major Injury	0.696 (0.691-0.701)	0.666 (0.661-0671)
Any Serious Outcome	0.584 (0.580-0.588)	0.587 (0.583-0.590)
Any Admission	0.548 (0.544-0.552)	0.540 (0.536-0.544)
Outcome of Interest for Ages 0 to 11 years	**AUC for Sacco Score (95% CI)**	**AUC for Unadjusted Sacco Score (95% CI)**
Mortality	0.933 (0.917-0.949)	0.937 (0.922-0.951)
Death on Arrival	0.884 (0.832-0.935)	0.889 (0.839-0.939)
Major Injury	0.697 (0.687-0.706)	0.699 (0.690-0.708)
Any Serious Outcome	0.584 (0.577-0.590)	0.578 (0.571-0.585)
Any Admission	0.525 (0.517-0.533)	0.519 (0.511-0.527)

Table 4. Area Under the Curve (AUC) for Receiver-Operator Curves for Primary and Secondary Outcomes. Regular and "unadjusted" Sacco Scores for pediatric trauma patients aged 0-18 years are shown in the upper section; scores for patients aged 0-11 years are shown in the lower section. In this context, an AUC of 0.500 would suggest the Sacco triage score is no better than a coin toss at predicting the outcome of interest while an AUC of 1.000 would indicate perfect accuracy.

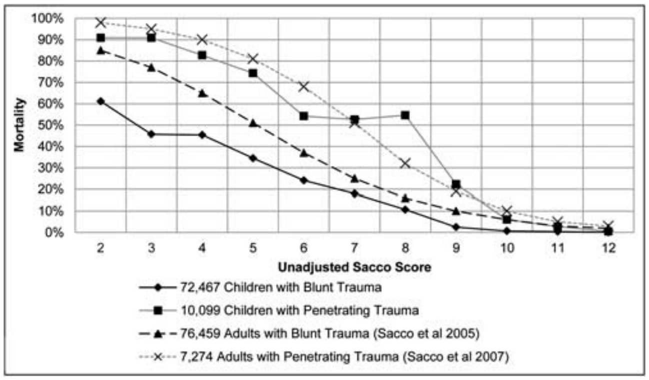

Figure 2. Trauma Mortality Rate by Unadjusted Sacco Score Graph of mortality rates as a function of Unadjusted Sacco Score. Pediatric data comes from the current study. Adult data comes from two previously published studies.[10,11] For this graph, Sacco Scores of 0 and 1 have been omitted due to lack of patients with these scores.

that shows similar STM performance in younger patients, whether or not the Sacco age adjustment subscore is included.

In this study, there were very few patients with Sacco Scores of 0 or 1, presumably because the reporting trauma centers rarely track trauma victims who are essentially dead at the scene. Such victims may be more common in a mass-casualty incident than they were in this dataset. However, in most cases such victims will be recognized as unsalvageable and therefore consume few medical resources.

Another important limitation is that most patients in this analysis come from individual trauma cases, not from mass-casualty incidents. The emergency departments, trauma services, and hospital units were typically providing routine care rather than being overloaded in a disaster situation. Outcomes in a disaster may be significantly worse than those seen in this registry population. A prospective validation of the STM in mass-casualty incidents, instead of retrospective validation against a registry database, would be more compelling, but such research is potentially costly, ethically challenging, and logistically difficult.

The original validation of the STM in adults used a different registry database, and was performed by a different group of investigators.[10,11] Variations in the underlying registry data, inclusion and exclusion rules, and statistical methods may all limit comparisons with prior studies.

Furthermore, not all trauma centers submit data to the NTDB. The data in the registry are submitted voluntarily from specific trauma centers in the United States primarily to maximize the number of data records, not to ensure regional or other demographic balance. Consequently, from this registry data one cannot extrapolate to national incidence and prevalence figures. Regional imbalances were tolerated because attempts to correct or "rebalance" the data statistically might introduce new imbalances while failing to help answer the study's primary research question. As many complete pediatric data records as possible were needed for this validation analysis, regardless of their region of origin.

Finally, other disaster triage methods were not validated against this study's pediatric data set, but could be in the future. The approach from this study could be used to compare various proposed triage methods in a head-to-head manner, as other researchers have done on a more limited scale.[13,14] Future research could help determine the best disaster triage method for children, or guide efforts to merge the best aspects of several methods into a novel, optimized approach. Further work could also assess the performance of STM in actual mass-casualty incidents.

Conclusion

This study demonstrates that the Sacco Triage Method, with or without its age adjustment term, is a highly accurate predictor of mortality in pediatric trauma patients in the NTDB registry. This triage method appears to be a valid strategy for the prioritization of injured children.

Future study may help simplify the Sacco Triage Method for first responders and others with minimal training in its use without loss of accuracy, and evaluate its performance in actual mass-casualty incidents.

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