Prehospital Physiologic Data and Lifesaving Interventions in Trauma Patients

Guarantor: COL John B. Holcomb, USA
Contributors: COL John B. Holcomb, USA*†; 2LT Sarah E. Niles, USA*; Charles C. Miller, PhD*; Denise Hinds, RN BSN*; James H. Duke, MD*; Frederick A. Moore, MD*

Background: The ability to accurately triage trauma patients can be difficult in the prehospital environment. Prehospital trauma scoring systems have been developed with a goal of determining which patients should be transported immediately to a trauma center, thus benefiting from critical personnel and resource-intensive lifesaving interventions (LSIs). A resource-based endpoint, LSIs, therefore might be the optimal endpoint of prehospital triage scoring and could be used to determine where patients are transported. We hypothesized that simple physiologic data available immediately upon scene arrival would prove predictive of the need for a LSI. Methods: Trauma patients transported from the injury scene by helicopter were eligible for entry into the study. Prehospital physiologic data and interventions were timed and recorded by flight medical personnel, whereas hospital vital signs, injuries, and interventions were prospectively recorded from the inpatient records. The motor component of the Glasgow Coma Scale was used as an indicator of neurologic function. LSIs were procedures deemed lifesaving by a multidisciplinary panel of trauma experts. Results: Physiologic data were collected from August 2001 to February 2002. Data were collected for 216 random patients transported by the Life Flight helicopter service. There were no differences between LSI and non-LSI patients in age, gender, or transport time, and 80 patients underwent 197 LSIs. The mean age was 33 ± 17 years, 73% of patients were male, 90% suffered blunt injury, the injury severity score was 14 ± 9, hypotension (systolic blood pressure of <90 mm Hg) was present in 14% of cases, and the mortality rate was 6%. Penetrating injury and increasing injury severity score were associated with LSI. Univariate analysis of the physiologic data immediately available in the field revealed that SBP of <90 mm Hg, motor score of <6, delayed capillary refill, and increasing pulse were significantly associated with a LSI. However, multivariate analysis revealed that only SBP of <90 mm Hg and motor score of <6 were associated with a LSI. When both variables were abnormal, 95% of patients required a LSI; when both variables were normal, 21% of patients required a LSI. Conclusions: The presence of hypotension or decreased motor score was correlated with the need for LSIs. However, normotensive patients with normal motor scores still frequently required LSIs. Optimal discrimination of this group of patients will require new analytic approaches.

*University of Texas Health Sciences Center, Houston, TX 77030.
†Uniformed Services University of the Health Sciences, Bethesda, MD 22089.

Presented at the 24th Annual Gary P. Wratten Surgical Symposium, April 8–10, 2002, Washington, DC.

The opinions expressed herein are the private views of the authors and are not to be construed as official or reflecting the views of the U.S. Department of Defense.

Reprints: COL John B. Holcomb, U.S. Army Institute of Surgical Research, 3400 Rawley E. Chambers Ave, Fort Sam Houston, TX 78234-6315; e-mail: John.Holcomb@amedd.army.mil.

This manuscript was received for review in April 2003. The revised manuscript was accepted for publication in September 2003.

Introduction

The ability to accurately triage trauma patients can be problematic in prehospital environments. Many prehospital triage scores have been developed to facilitate this process, perhaps demonstrating that a good deal of uncertainty remains in these methods.[1–18] The primary reason to perform prehospital scoring is to determine whether patients should be transported immediately to a trauma center (TC) and thus benefit from the TC's ability to rapidly provide lifesaving interventions (LSIs), resulting in the survival of patients who would otherwise have died.[19–26]

The potential benefit of TCs is related to the concentration of experienced personnel and technology at one location that specializes in the care of seriously injured patients. Organized TCs have been shown to decrease rates of preventable death in the intermediate group of patients who arrive seriously ill. Mortality rates in current mature TCs are approximately 3% of admissions, and death usually occurs among patients who have devastating injuries and a very low probability of survival, despite very aggressive diagnostic and interventional maneuvers.[27] Using death as the primary endpoint of a prehospital triage tool identifies only the small numbers of patients who received LSIs and died at the TC, rather than those who received LSIs and benefited from the interventions. Others have recommended using an injury severity score (ISS) of >15 as an indicator of appropriate triage; however, these data are not available until hospital discharge. This highlights the fact that, although ISS is often appropriately used to retrospectively compare outcomes between groups of patients, the data that are used to compile the ISS are not available until discharge from the hospital. Therefore, the ISS is not a tool that can be used for prehospital or even emergency department triage. More importantly, up to 25% of patients with low ISSs (scores of 1–9) required the resources available at TCs.[27]

A more useful prehospital triage tool would identify patients who actually required a LSI.[28] This resource-based triage endpoint would focus on patients who were transported to a TC and received and benefited from LSIs.[9] Those who were transported to a TC, did not receive LSIs, and survived would represent the group that perhaps could have been transported to a non-TC and fared just as well. Many studies have demonstrated that trauma systems have not developed a sensitive and specific prehospital triage tool capable of identifying patients who would or would not benefit from evaluation at the TC.[29,30] In an initial attempt to develop a prehospital triage tool based only on prehospital data whose endpoint is resource based, we hypothesized that physiologic data immediately available upon scene arrival would prove predictive of the need for a LSI.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302 Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number

1. REPORT DATE **01 JAN 2005**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Prehospital physiologic data and lifesaving interventions in trauma patients**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Holcomb J. B., Niles S. E., Miller C. C., Hinds D., Duke J. H., Moore F. A.,**	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **United States Army Institute of Surgical Research, JBSA Fort Sam houston, TX 78234**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT	b ABSTRACT	c THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Methods

A random convenience sample of trauma patients transported from the scene, by a Life Flight system helicopter, to Memorial Hermann Hospital, an urban, level I TC in Houston, Texas, between August 1, 2001 and March 7, 2002 (7 months), were eligible for the study. This study was approved by the Committee for the Protection of Human Subjects of the University of Texas Health Science Center at Houston. The Life Flight helicopter service consists of three Eurocopter BK 117B helicopters. An experienced pilot, flight medic, and nurse constitute the helicopter flight crew. Trauma patients discharged home from the emergency department (25%) were not included in this data set. Patient inclusion criteria were as follows: (1) transport directly from the incident scene and (2) an injury necessitating admission to the hospital. All data were collected on a standardized data collection form and entered into a research database specifically designed for this study. A single research nurse performed all data entry. Patients were routinely monitored from the scene, during transport, and into the emergency center with a Propaq 206 monitor (Welch Allyn, Beaverton, Oregon). The physiologic data used in this study were manually recorded on the run sheet from the screen of the portable monitor. Vital signs, Glasgow Coma Scale score, capillary refill, age, gender, mechanism of injury, and interventions were recorded on the flight charts (see Table II). The most abnormal physiologic data recorded during the flight were used for data analysis. Patients with injuries requiring LSIs were compared with those who did not require LSIs. Prehospital LSIs (P-LSIs) were based on procedures outlined in the Life Flight protocols (Table II). Hospital-based LSIs (H-LSIs) were determined based on review of all International Classification of Diseases, 9th Revision, Clinical Modification procedure codes entered into the trauma registry for a 12-month sample of admitted trauma patients. Those 306 procedures were then classified as LSIs (153 procedures in 13 major groups) or non-LSIs by a multidisciplinary panel of trauma experts (see Table III).

P-LSIs were timed and recorded by flight medical personnel, whereas final diagnosis, intensive care unit, intermediate, floor, or observation unit admission, H-LSIs, ISS, and death were prospectively recorded or calculated from the inpatient records by a single research nurse. By definition, all LSIs must have occurred within 24 hours after injury.

The predictive elements were used to correctly identify the patients who had a LSI and should be transported to the TC, thus defining sensitivity. Similarly, the predictive elements were used to correctly identify the patients who did not need a LSI and did not require TC care, thus defining specificity. Univariate associations between predictor variables and LSIs were estimated with contingency table analyses (categorical variables) or *t* tests or Wilcoxon rank sum tests (continuous or near-continuous data) as appropriate. Multivariate tests of association were computed with multivariate logistic regression analyses. Because the goal of the multivariate analyses was to construct probability estimates that could be used readily in the field, we used continuous-variable cutoff points that are commonly used in the clinical arena. A Glasgow Coma Scale motor function score of <6 was considered abnormal. A systolic blood pressure (SBP) of <90 mm Hg was considered hypotensive. Indicator variables for these conditions were created and included in multivariate logistic regression models. Initial model evaluation was conducted with stepwise selection. Subsequently, best-subset regression was performed; only variables that were statistically significant and contributed to the stability of the regression estimates were retained in the final model. Multivariate probabilities were computed by standard transformation of the logistic regression odds. Sensitivity and specificity of the final model were evaluated with receiver operating characteristic (ROC) analyses. All computations were performed with SAS version 8.02 in Windows 2000 (SAS Institute, Cary, North Carolina). The null hypothesis was rejected at $p < 0.05$.

Results

The demographic features of the 216 patients included in the study are presented in Table I. Where appropriate, quartiles were established for descriptive and physiologic data. Ages were not different between groups, and male gender did not predispose patients to a LSI. Increasing patient age did not increase the requirement for a LSI. Longer transit time was not associated with LSIs. Not unexpectedly, death, increasing ISS, and penetrating injury were associated with LSIs. The majority of patients did not require a LSI (63%); all of those who died (6%) received a LSI, whereas 33% of survivors received a LSI. Patients were admitted equally to the intensive care unit (46%) and the floor (51%). However, LSIs were performed on intensive care unit patients (66%) more frequently than floor patients (8%).

LSIs were subdivided into P-LSIs and H-LSIs. The majority of P-LSIs were intubations, which were performed for 35 patients, of whom 34% ultimately died (Table II). Other P-LSIs were rarely performed and were associated with high mortality rates. Table III documents that H-LSIs were performed more frequently (31% of patients) and with a lower mortality rate (15%) than P-LSIs. The most frequently performed H-LSI was transfusion of packed red blood cells, with a mean transfusion during the first 24 hours of 7 ± 6 units and a mortality rate of 13%. Abdominal operations and chest tubes were used frequently and with significant mortality rates.

The physiologic variables available at the injury scene are evaluated in Table IV. Univariate analyses demonstrated that increasing pulse, delayed capillary refill, abnormal motor score, and SBP of <90 mm Hg were associated with a LSI. Multivariate analysis demonstrated that abnormal motor score (score of <6) and SBP of <90 mm Hg were independently associated with LSIs (Table V). These data documented that trauma patients with SBP of <90 mm Hg and motor scores of <6 had a LSI performed 95% of the time. When one or the other variable was present, a LSI was performed 61 to 77% of the time. When neither was present, a LSI was still performed 21% of the time. Figure 1 shows a ROC curve for the final logistic regression model. The area under the curve was 74.4%, demonstrating good model discrimination.

The 33 (21%) patients who received LSIs but had normal motor scores and blood pressure were analyzed as a separate group. These patients did not reveal any physiologic variables that predicted a LSI, and none of the patients died. The penetrating injury rate was significantly increased in this group (24%), compared with the entire study population (10%). P-LSIs (three intubations and one needle decompression, for four patients) were performed less frequently than in the larger study

TABLE I

PATIENT DEMOGRAPHIC CHARACTERISTICS AND UNIVARIATE ANALYSES

Variable	No. of Patients (%)	No. with LSIs (%)	Odds Ratio[a]	95% Confidence Interval[b]	p^c
All patients	216 (100)	80 (37)			
Gender					
Female	58 (27)	23 (40)	1.16	0.63–2.16	0.64
Male	158 (73)	57 (36)			
Injury					
Blunt	195 (90)	66 (34)	0.26	0.10–0.67	0.005
Penetrating	21 (10)	14 (67)			
Age (yr)					
Mean	33 ± 17				
2–18	45 (21)	17 (38)	1.01	1.00–1.02	0.90 (0.62)
19–30	62 (29)	21 (34)			
31–44	54 (25)	20 (37)			
45–83	54 (25)	22 (41)			
ISS					
Mean	12.2 ± 9.2				
0–4	54 (25)	3 (6)	1.17	1.12–1.23	0.0001 (0.001)
5–8	24 (11)	5 (21)			
9–12	74 (34)	28 (38)			
13–34	64 (30)	44 (69)			
Transit time (min)					
Mean	15 ± 7				
6–10	54 (25)	23 (43)	0.96	0.92–1.01	0.15 (0.09)
11–12	40 (18)	11 (28)			
13–17	62 (29)	28 (45)			
18–47	60 (28)	18 (30)			
Admission status					
Floor	107 (50)	9 (8)	21.3	9.7–46.8	0.0001 (0.0001)
Intensive Care Unit	102 (48)	67 (66)			
Morgue	4 (2)	4 (100)			
Length of stay (days)					
ICU					
Mean	1.4 ± 4.1				
0	142 (68.3)	24 (16.9)	15.3	7.52–31.3	0.0001
1–38	66 (31.7)	50 (75.8)			
Floor					
Mean	5.4 ± 6.8				
0–1	14 (6.7)	12 (85.7)	1.02	0.98–1.06	0.0001 (0.33)
2–3	72 (34.6)	13 (18.1)			
4–8	67 (32.2)	30 (44.8)			
9–63	55 (26.4)	19 (34.6)			
Total					
Mean	6.8 ± 9.2				
1–2	48 (23.1)	9 (18.8)	1.06	1.01–1.11	0.0001 (0.02)
3–5	52 (25.0)	13 (25.0)			
6–9	51 (24.5)	22 (43.1)			
10–101	57 (27.4)	30 (52.6)			
Alive	203 (97)	67 (33)	0.02	0.01–0.31	0.0001
Dead	13 (6)	13 (100)			

[a] For dichotomous variables, the odds ratio represents a test against a reference category whose referent odds ratio is equal to 1. For continuous data, the odds ratio refers to the increase in odds associated with a 1-unit increase in the variable value. Although continuous data are presented in quartiles, the odds ratios are calculated against the continuous variable.

[b] This reflects the units against which its companion odds ratio is computed. Confidence intervals are test based.

[c] p, probability of type I statistical error (common p value). Values without parentheses are Pearson χ^2 probabilities. Probability values in parentheses are univariate logistic regression likelihood ratio p values.

population (13% vs. 19%). H-LSIs (6 intubations, 13 chest tubes, and 10 operations and transfusions) were performed for 29 patients. The mean ISS was 14 ± 8 and the mean age for this group was 38 years (5 years older than the study group as a whole).

Discussion

Hospital-based trauma scoring systems utilize data that are available only after patients have been thoroughly evaluated, have been operated on, or are ready for discharge. These hospi-

TABLE II

LSIS AND ASSOCIATED MORTALITY RATES

	No. of P-LSIs (no. of patients)	Death, no. of patients (%)
Total interventions	43 (37)	12 (32%)
Intubations	35 (35)	12 (34%)
Needle thoracentesis	3 (3)	0 (0%)
Cricothyroidotomy	2 (2)	1 (50%)
Pericardiocentesis	2 (2)	1 (50%)
CPR	1 (1)	1 (100%)

CPR, cardiopulmonary resuscitation.

TABLE III

H-LSIS WITHIN 24 HOURS AFTER ADMISSION AND OVERALL MORTALITY RATE

	No. of H-LSIs (No. of Patients)	Death, No. of Patients (%)
Total interventions	152 (68)	10 (15%)
Intubation	7 (7)	0
Chest tube	26 (26)	3 (12%)
OR, abdomen	49 (20)	5 (25%)
OR, head	9 (6)	3 (50%)
OR, chest	8 (4)	1 (25%)
OR, neck	5 (4)	0
OR, face	1	0
OR, spine	1	0
OR, extremities	1	0
PRBC transfusion (units)	279 (39)	5 (13%)
Arteriogram	3 (3)	1 (33%)
Defibrillation	2	1 (50%)
CPR	1	0

OR, operating room; PRBC, packed red blood cells; CPR, cardiopulmonary resuscitation.

tal scoring systems are primarily used for research, quality assurance programs, and comparisons of different institutions and systems. The goals of a clinically useful prehospital triage rule should be somewhat different. A practical prehospital triage rule should be simple to remember, be easy to determine, and most importantly predict which patients will require TC treatment or not.[14] A prehospital triage rule should assist medical personnel working outside the sheltered environment of the hospital with decision-making regarding optimal patient transport. In the civilian environment, this usually concerns the issue of transport to a TC or non-TC. In the military arena, this triage rule would determine when evacuation should occur, rather than the location.

Trauma systems decrease mortality rates, compared with nontrauma systems.[19-26] They accomplish this by rapidly moving patients to centers where interested experienced personnel can rapidly perform LSIs. However, one of the major problems with current prehospital scoring and triage rules are that they purposely overtriage patients to the TC, i.e., they are not specific enough to reliably predict which patients do not require TC care. Therefore, many patients who are transported to the TC do not benefit from the TC level of intervention and expertise. These patients "clog up" the TC system, not infrequently slowing required interventions for seriously injured patients. The American College of Surgeons Committee on Trauma[31] states that overtriage rates of 30 to 50% (specificity) are required to ensure that seriously injured patients are transported to the TC and not undertriaged (5–10% acceptable rate, sensitivity) to locations where LSIs might be delayed. When both SBP and motor scores were normal, 21% of patients still required LSIs. This group of patients should not be triaged to a non-TC, and further work is required to develop a system that can identify these at-risk patients. Furthermore, determining what LSIs are required may determine trauma-training requirements.

Adding mechanism and anatomic injury information to existing prehospital triage rules has been theorized to increase the sensitivity of the trauma triage algorithms. However, in the absence of physiologic abnormalities, these additions often greatly increase the overtriage rate, resulting in the transport of a large number of patients who do not benefit from the expertise at the TC.[29] Similarly, using the judgment of prehospital personnel as a triage criterion has not been shown to be independently predictive of TC triage.[13] A new focus on serial physiologic parameters, with the technologic evolution of noninvasive monitors and handheld personal computers, may allow new prehospital triage rules to be developed that are sensitive, specific, and useful for prehospital trauma providers.

The use of LSI as an endpoint for prehospital triage is not a new concept. Baxt et al.[9] and Garner et al.[29] suggested that a resource-based outcome or a LSI, rather than death, is the optimal endpoint of prehospital triage. Baxt et al.[9] combined Glasgow Coma Scale motor score, systolic hypotension, and penetrating mechanism and demonstrated a sensitivity and specificity of 92%. Garner et al.[29] recently evaluated four different systems and concluded that Glasgow Coma Scale motor score and systolic hypotension had the strongest association with severe injury; the authors suggested prospective data collection to evaluate their recommendation. The work described herein builds on their efforts. Future studies (currently ongoing) will describe the incorporation of electronic physiologic data recording suitable for continuous data analysis. These data may be used to derive an algorithm useful in the remote trauma triage decision-assist devices currently being developed in the Land Warrior integrated uniform system.

The data presented document that trauma patients with SBP of <90 mm Hg and motor scores of <6 had a LSI performed 95% of the time. When one or the other variable was present, a LSI was performed 61 to 77% of the time. When neither was present, a LSI was still performed 21% of the time. All patients who ultimately died demonstrated an abnormal motor score, hypotension, or both. Patients who were physiologically normal still required a LSI 21% of the time, but all lived. The latter group represents patients who may initially appear physiologically normal but still require a LSI. These are the patients who could easily be undertriaged to a non-TC and potentially have LSIs delayed, with increased morbidity and mortality rates. Luna et al.[33] documented a similar finding. New methods of prehospital triage may be required for these patients, possibly in the arena of real-time analysis of electronically captured, continuous or near-continuous, noninvasive, physiologic data.[32,33] The lack of prehospital real-time analysis of easily available physiologic data is not in keeping with current hospital-based practice, where

TABLE IV

PREHOSPITAL PHYSIOLOGIC CHARACTERISTICS WITH UNIVARIATE ANALYSES

Variable	No. of Patients (%)	No. with LSIs (%)	Odds Ratio	95% Confidence Interval	p
All patients	*216 (100)*	*80 (37.0)*			
Pulse (beats/min)					
Mean	102 ± 23				
48–83	50 (23)	15 (30)	1.02	1.01–1.03	0.02 (0.01)
84–99	52 (24)	17 (33)			
100–115	58 (27)	17 (29)			
116–186	56 (26)	31 (55)			
Capillary refill					
Delayed (>2 s)	19 (9)	17 (90)	17.43	3.90–77.88	0.0001
Normal (<2 s)	183 (91)	60 (33)			
Motor score					
Abnormal (<6)	51 (24)	37 (73)	7.50	3.70–15.20	0.0001
Normal (=6)	165 (76)	43 (26)			
SBP					
<90 mm Hg	31 (14)	27 (87)	16.81	5.61–50.37	0.0001
≥90 mm Hg	185 (86)	53 (29)			
Respiratory rate (breaths/min)					
Intubated	19 (9)				
Nonintubated mean	22 ± 9				
6–18	28 (13)	13 (46)	0.98	0.94–1.03	0.12 (0.40)
19–20	28 (13)	8 (29)			
21–24	76 (35)	18 (24)			
24–100	65 (30)	24 (37)			

Statistical analyses are as in Table I.

TABLE V

PROBABILITY OF REQUIREMENT FOR LSI

N	Motor Score	SBP	Probability of LSI[a] (%)	Death (%)
151	6	≥90 mmHg	21	0
34	<6	≥90 mmHg	61	3 (9)
14	6	<90 mmHg	77	1 (7)
17	<6	<90 mmHg	95	9 (53)

[a] Multiple logistic regression probability estimates.

these data are monitored by the trauma team and the trends are integrated and used by the trauma team leader at all major decision points.[34]

Figure 1 is a ROC curve derived from a multivariate logistic regression model. This is a two-variable model with indicator values for abnormal Glasgow Coma Scale motor score (<6) and abnormal SBP (<90 mm Hg). Classification accuracy of the model is considered to be good, with 74.4% of the graph area being under the curve (c statistic). The ROC curve (Fig. 1) demonstrates that, when sensitivity is high (85%), specificity is less than optimal (~30%). Identification of additional variables in future studies may improve model discrimination. As the current estimates stand, the high specificity is consistent with the American College of Surgeons overtriage plan, so as not to miss injured patients.

The strength of this study resides in two areas. First, all data were collected by one Life Flight system, with transport by one of three helicopters that delivered trauma patients directly from the injury scene to one urban regional TC. All prehospital medical personnel underwent uniform training and practiced with the same treatment protocols. All physiologic data were recorded with the same type of electronic monitor. Second, the study population had a relatively high incidence of hypotension (14%) and altered motor scores (24%). This led to LSIs being performed for 37% of transported patients, probably reflecting a selection bias of patients transported by helicopter. There are two principal weaknesses in this study. The first was the small number of patients available for evaluation. This study was intended to be an initial effort, documenting that prehospital data collection was feasible and that LSI was a reasonable endpoint. The second was that the performance of a LSI and the requirement for a LSI are not necessarily the same. This distinction will be difficult to establish. The Life Flight personnel are all highly trained and experienced, with a rigorous flight review process for every patient and procedure. Furthermore, all patients who died received a LSI, whereas only 37% of those who lived received a LSI. This evaluation suggests that LSIs were not performed without appropriate clinical justification.

Future studies will expand on the described approach using physiologic trends to determine the minimum data set necessary to predict the need for LSIs. The ultimate goal of this project is to place in the hands of prehospital medical providers a

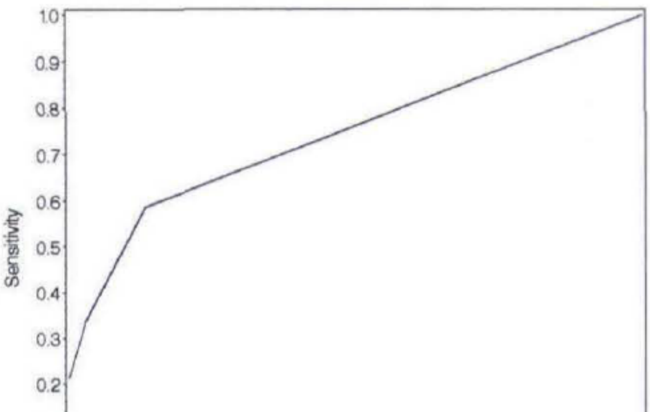


Fig. 1. ROC curve describing the screening characteristics of the logistic regression model. The value of 1 − specificity is equal to the false-positive rate, as given by false-positive results divided by nonevents. At any given point along the line, the tradeoff between sensitivity and specificity can be observed. The area under the curve is 74.4%.

decision-assist device that will assist them in arriving at the critical treatment, triage, and evacuation determinations in less obvious cases. Using these data will also yield a data-driven approach for determining what sensors are required for the Land Warrior system, rather than arbitrary preselection.

With the increasing use of automated data analysis, field-expedient decision-assist systems should be provided to prehospital medical personnel.[35] New technology now allows nearly continuous acquisition of multiple, noninvasive, prehospital, physiologic data. Recording physiologic data from large numbers of trauma patients will create the physiologic database necessary for this effort. New approaches to physiologic data analysis will be required to provide trend analysis of noninvasive physiologic data for the on-scene medics. Rapid communication from the prehospital environment to the hospital is frequently unreliable, emphasizing the need for moving physiologic data analysis systems into the prehospital arena. Although these systems are used in a few intensive care unit settings, no such clinical decision-support tools have been developed for the civilian prehospital medical community, much less the more austere military environment.[35-39] Integration of these physiologic data will allow the development of software that may facilitate real-time analysis and the deployment of decision-assist devices that are small, rugged, rapid, and accurate to assist medics in their prehospital triage decisions.

Acknowledgment

This study was supported by grants from the U.S. Army Combat Casualty Care Program and the Defense Advanced Research Projects Agency.

References

1. Champion HR, Sacco WJ, Carnazzo AJ, Copes W, Fouty WJ: Trauma score. Crit Care Med 1981; 9: 672–6.
2. West JG, Murdock MA, Baldwin LC, Whalen E: A method for evaluating field triage criteria. J Trauma 1986; 26: 655–9.
3. Rhodes M, Perline R, Aronson J, Rappe A: Field triage for on-scene helicopter transport. J Trauma 1986; 26: 963–9.
4. Morris JA Jr, Auerbach PS, Marshall GA, Bluth RF, Johnson LG, Trunkey DD: The Trauma Score as a triage tool in the prehospital setting. JAMA 1986; 256: 1319–25.
5. Hedges JR, Feero S, Moore B, Haver DW, Shultz B: Comparison of prehospital trauma triage instruments in a semi rural population. J Emerg Med 1987; 5: 197–208.
6. Knudson P, Frecceri CA, DeLateur SA: Improving the field triage of major trauma victims. J Trauma 1988; 28: 602–6.
7. Champion HR, Sacco WJ, Copes WS, Gann DS, Gennarelli TA, Flanagan ME: A revision of the Trauma Score. J Trauma 1989; 29: 623–9.
8. Baxt WG, Berry CC, Epperson MD, Scalzitti V: The failure of prehospital trauma prediction rules to classify trauma patients accurately. Ann Emerg Med 1989; 18: 1–8.
9. Baxt WG, Jones G, Fortlage D: The trauma triage rule: a new, resource-based approach to the prehospital identification of major trauma victims. Ann Emerg Med 1990; 19: 1401–6.
10. Emerman CL, Shade B, Kubincanek J: A comparison of EMT judgment and prehospital trauma triage instruments. J Trauma 1991; 31: 1369–75.
11. Emerman CL, Shade B, Kubincanek J: Comparative performance of the Baxt Trauma Triage Rule. Am J Emerg Med 1992; 10: 294–7.
12. Phillips JA, Buchman TG: Optimizing prehospital triage criteria for trauma team alerts. J Trauma 1993; 34: 127–32.
13. Fries GR, McCalla G, Levitt MA, Cordova R: A prospective comparison of paramedic judgment and the trauma triage rule in the prehospital setting. Ann Emerg Med 1994; 24: 885–9.
14. Meredith W, Rutledge R, Hansen AR, et al: Field triage of trauma patients based upon the ability to follow commands: a study in 29,573 injured patients. J Trauma 1995; 38: 129–135.
15. Esposito TJ, Offner PJ, Jurkovich GJ, Griffith J, Maier RV: Do prehospital trauma center triage criteria identify major trauma victims? Arch Surg 1995; 130: 171–6.
16. Sampalis JS, Tamim H, Nikolis A, Lavoie A, Williams JI: Predictive validity and internal consistency of the pre-hospital index measured on-site by physicians. Accid Anal Prev 1996; 28: 675–84.
17. Bond RJ, Kortbeek JB, Preshaw RM: Field trauma triage: combining mechanism of injury with the prehospital index for an improved trauma triage tool. J Trauma 1997; 43: 283–7.
18. Franklin GA, Boaz PW, Spain DA, Lukan JK, Carrillo EH, Richardson JD: Prehospital hypotension as a valid indicator of trauma team activation. J Trauma 2000; 48: 1034–9.
19. West JG, Trunkey DD, Lim RC: Systems of trauma care: a study of two counties. Arch Surg 1979; 114: 455–60.
20. Trunkey DD: Trauma. Sci Am 1983; 249: 28–35.
21. Cales RH, Trunkey DD: Preventable trauma deaths: a review of trauma care systems development. JAMA 1985; 254: 1059–63.
22. Mullins RJ, Veum-Stone J, Helfand M, et al: Outcome of hospitalized injured patients after institution of a trauma system in an urban area. JAMA 1994; 271: 1919–24.
23. Peitzman AB, Courcoulas AP, Stinson C, Udekwu AO, Billiar TR, Harbrecht BG: Trauma center maturation: quantification of process and outcome. Ann Surg 1999; 230: 87–94.
24. Nathens AB, Jurkovich GJ, Maier RV, et al: Relationship between trauma center volume and outcomes. JAMA 2001; 285: 1164–71.
25. Pasquale MD, Peitzman AB, Bednarski J, Wasser TE: Outcome analysis of Pennsylvania trauma centers: factors predictive of nonsurvival in seriously injured patients. J Trauma 2001; 50: 465–74.
26. Margulies DR, Cryer HG, McArthur DL, Lee SS, Bongard FS, Fleming AW: Patient volume per surgeon does not predict survival in adult level I trauma centers. J Trauma 2001; 50: 597–603.
27. Rogers FB, Osler TM, Shackford SR, Martin F, Healey M, Pilcher D: Population-based study of hospital trauma care in a rural state without a formal trauma system. J Trauma 2001; 50: 409–14.
28. Zimmer-Gembeck MJ, Southard PA, Hedges JR, et al: Triage in an established trauma system. J Trauma 1995; 39: 922–8.
29. Garner A, Lee A, Harrison K, Schultz CH: Comparative analysis of multiple-casualty incident triage algorithms. Ann Emerg Med 2001; 38: 541–8.
30. Kane G, Engelhardt R, Celentano J, et al: Empirical development and evaluation of prehospital trauma triage instruments. J Trauma 1986; 25: 482–89.
31. American College of Surgeons Committee on Trauma: Resources for the Optimal Care of the Injured Patient. Chicago, IL, American College of Surgeons, 1999.

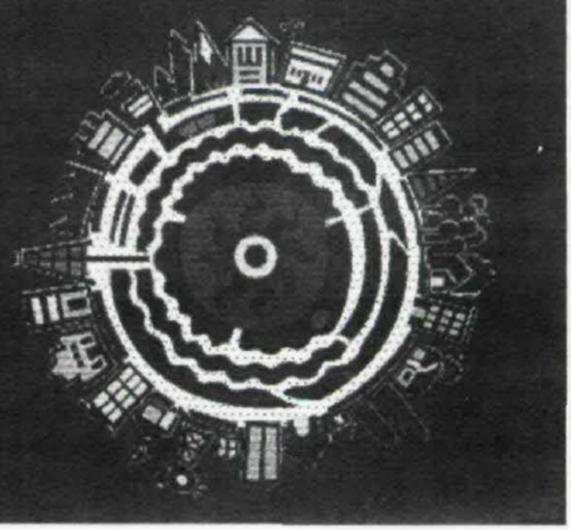
32. Luna GK, Eddy AC, Copass M: The sensitivity of vital signs in identifying major thoracoabdominal hemorrhage. Am J Surg 1989; 157: 512–15.
33. Baxt WG: Complexity, chaos and human physiology: the justification for non-linear neural computational analysis. Cancer Lett 1994; 77: 85–93.
34. Roberts DA, Holcomb JB, Parker BE, et al: Utility of polynomial neural networks to predict mortality in swine with severe uncontrolled hemorrhage: a retrospective study. J Trauma 2002; 52: 130–5.
35. Shoemaker WC, Wo CC, Chan L, et al: Outcome prediction of emergency patients by noninvasive hemodynamic monitoring. Chest 2001; 120: 528–37.
36. Zupan B, Porenta A, Vidmar G, Aoki N, Bratko I, Beck JR: Decisions at hand: a decision support system on handhelds. Medinfo 2001; 10: 566–70.
37. McKinley BA, Moore FA, Sailors RM, et al: Computerized decision support for mechanical ventilation of trauma induced adult respiratory distress syndrome: results of a randomized clinical trial. J Trauma 2001; 50: 415–25.
38. McKinley BA, Sailors RM, Glorsky SL, et al: Computer-directed resuscitation of major torso trauma. Shock 2001; 15(Suppl): 46.
39. McKinley BA, Cocanour CS, Kozar RA, et al: Normal vs supranormal O_2 delivery goals in shock resuscitation: the response is the same. J Trauma 2002; 53: 825–32.

Your Invitation to Attend the

GLOBAL HEALTH SUMMIT

June 5, 2005

Philadelphia, Pennsylvania



Join public health professionals and global health advocates from around the world for a preview of the U.S. Surgeon General's Call to Action on his upcoming ***Report on Global Health***.

The primary purpose of the Summit is to seek individual and organizational input that will assist in the development of the ***Report on Global Health*** and also to seek advice on needed collaborative action by national and international stakeholders in advancing the health of the citizens of the world community.

The Summit is open to individuals and organizations concerned with the health and related economic challenges and opportunities facing the global community.

Focus areas will include:

- International Safety
- Maternal and Child Health
- Chronic Disease
- Environmental Health
- Priority Health Problems and Disparities
- Health of Transient Populations
- Mental Health & Individual Behavior
- Infectious Disease
- Indigenous & Multi-Cultural Populations
- Self-Help Programs
- Social Equity
- Economic impact of Global Health

Global Health Summit

June 5th, Wyndham Franklin Plaza,

17th & Race Streets, Philadelphia, PA 19103

Following the summit, the 2005 Public Health Professional Conference will be held from June 6th - 9th at the same location.

For more information or to register, call toll-free (866)544-9677 or visit www.globalhealthsummit.org

*The Global Health Summit is sponsored by the **PHS Commissioned Officers Foundation for the Advancement of Public Health** in association with the U.S. Department of Health and Human Services and other collaborating national and international health organizations.*

Copyright of Military Medicine is the property of Association of Military Surgeons of the United States and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.