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The Major Trauma Outcome Study: Establishing National Norms for Trauma Care

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The Major Trauma Outcome Study (MTOS) is a retrospective descriptive study of injury severity and outcome coordinated through the American College of Surgeons' Committee on Trauma. From 1982 through 1987, 139 North American hospitals submitted demographic, etiologic, injury severity, and outcome data for 80,544 trauma patients. Motor vehicle related injuries were most frequent (34.7%). Twenty-one per cent of patients had penetrating injuries. The overall mortality rate was 9.0%. The mortality rate for direct admissions was strongly related to the presence of serious head injury, 5.0% and 40.0%, when head injuries were ≤ AIS (Abbreviated Injury Scale) 3 or ≥ AIS 4, respectively. Survival probability norms use the Revised Trauma Score, Injury Severity Score, patient age, and injury mechanism. Patients with unexpected outcomes were identified and statistical comparisons of actual and expected numbers of survivors made for each institution. Results provide a description of injury and outcome and support evaluation and quality assurance activities.

Injury is a public health problem of vast proportions. It is the leading cause of death for persons below the age of 44 years and the fourth leading cause for all ages (32). For ages 1 to 34, motor vehicle crashes are the most frequent cause of death (3). Approximately 150,000 Americans die annually from intentional and unintentional injury and an additional 400,000 persons are permanently disabled (32). The approximately 3.6 million hospital admissions each year for injury average more than 7 days per hospital stay (23). More than 4 million potential years of productive life are lost annually due to injury, exceeding the losses for heart disease, cancer, and stroke combined (31). The annual national cost of accidental injury is estimated to be $118 billion, approximately 50% of which is due to motor vehicle related injuries (32).

The prevalence and serious implications of injury have, in general, been passively accepted. In 1966, the National Academy of Sciences characterized accidental death and disability as the "neglected disease of modern society" (30). Nearly 20 years later, the Committee on Trauma Research of the National Research Council entitled its report on trauma *Injury in America: A Continuing Public Health Problem* (31). Approximately 2.5 million Americans died from injuries between the publication dates of those two government reports (30), with little focused effort to alleviate problems noted in the earlier study. *Injury in America* noted that the lack of trauma data is so severe "that effective programs of injury prevention and care evaluation cannot be accomplished." Continuous, systematic trauma data collection efforts are therefore essential.

Methods to classify disease severity (24, 29), are widely used for comparing patient samples, for measuring changes in patient conditions, and for evaluating physicians and treatment programs. Although several injury severity scales were developed and used in the 1970's (4, 12, 15, 28, 34), most were not stringently evaluated for their reliability and validity. Recognizing a need for improved methods to evaluate trauma care, trauma surgeons agreed in 1982 to pool data of injured patients and to develop and test survival probability norms based on severity indices considered to be "state of the art." This effort, initiated and organized by Doctors Champion and Frey and coordinated by the American College of Surgeons Committee on Trauma (ACSCOT), is the Major Trauma Outcome Study (MTOS).

The initial objectives of the MTOS were to develop national norms for trauma care that could be used by hospitals for quality assurance and EMS system man-

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agement. Hospitals could compare their mortality with the norms based on the management of injuries of similar severity. Patients who died from injuries from which they were predicted to survive or who survived injuries from which they were predicted to die could be identified for peer review. It was anticipated that trauma system managers would use these norms in trauma center designation and in monitoring hospital care. It was also anticipated that research into the outcome, rehabilitation, and costs of trauma care would evolve from this national database.

Demographic, etiologic, injury severity, and outcome data for more than 120,000 trauma patients treated at more than 140 hospitals from the U.S., Canada, Australia, and the United Kingdom have been submitted to MTOS since 1982. The data have been analyzed periodically and confidential results sent to participating institutions to support outcome evaluations and quality assurance activities. This paper presents results of the August 1988 MTOS analysis of data for 80,544 trauma patients from 139 U.S. and Canadian institutions, submitted from October 1982 through 1987.

METHODS

Participants and Data Collection. Study institutions are located throughout the United States and Canada. At each site, a physician project director supervises nurses or quality assurance personnel who collect patient data. Patients qualifying for the database included all in-hospital trauma deaths (including those later identified as "dead on arrival" if no therapies were started in hospital) *and* either all hospital admissions due to trauma *or* all injured patients admitted to intensive care during their hospital stay. The latter group (all deaths and all ICU admissions) was motivated by the need of some institutions to limit data collection to a critical subset of patients most appropriate for quality assurance and outcome evaluations.

Submitted data included:

1) Demographics;

2) Assessments of physiologic status at the injury scene; at emergency department admission; and 1 hour post admission;

3) Definitive anatomic injury diagnoses at patient discharge or death, obtained from patient charts, radiology reports, or autopsies;

4) Cause of injury;

5) Patient outcomes, i.e., survival/death at discharge from the acute care hospital, length of stay in the intensive care unit (ICU) and in the hospital.

Data Management. Data forms were sent to the study analysis center in Washington, DC, where anatomic injury descriptions were coded according to the *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM) (17), an injury taxonomy, and for severity using the Abbreviated Injury Scale (AIS), 1980 and 1985 versions (1, 2). Centralized coding was done by a small group of uniformly trained persons to maximize the consistency of data and analysis results. Extensive quality control procedures were used to minimize coding variation and errors, to reconcile keypunched and submitted data, and to ensure the accuracy of submitted data. When necessary, participating hospitals were asked to confirm, clarify, or supplement missing, unusual, or incongruous data.

Severity Indices. Both physiologic and anatomic indices are required to effectively characterize injury severity. The Revised Trauma Score (RTS) (13), a physiologic index of injury severity, is computed from coded values (0–4) of the Glasgow Coma Scale (GSC_c), systolic blood pressure (SBP_c) and respiratory rate (RR_c), obtained on emergency department admission (Table I). These values are multiplied by weights determined by logistic regression of a baseline data set

$$RTS = 0.9368(GCS_c) + 0.7326(SBP_c) + 0.2908(RR_c).$$

The RTS takes on values between 0 and 7.8408. Higher values are associated with improved prognoses. The RTS has been shown to more reliably predict outcome than its predecessor, the Trauma Score (12). The unweighted sum of coded RTS variables has been proposed by the American College of Surgeons for field triage of injured patients (18).

The Injury Severity Score (4, 6) is an index of anatomic injury severity that takes values from 1 to 75. Higher scores generally indicate more severe injuries. The ISS is based on the Abbreviated Injury Scale (AIS). The AIS is a list of several hundred injuries, each with an assigned severity score that can range from 1 (minor injuries) to 6 (injuries that are nearly always fatal). To compute the ISS, a patient's injuries are sorted into six body regions: head and neck, face, chest, abdominal and pelvic contents, extremities and pelvic girdle, and external. If the patient has any AIS 6 injury, the ISS is 75 by definition. Otherwise, the highest AIS severity score in each of the six body regions is identified, and the squares of the largest three are added to obtain the ISS.

Outcome Norms. Survival probability norms using the TRISS severity index (5, 12, 14) are the basis for the MTOS analyses supporting quality assurance activities and outcome-based care evaluation. TRISS is based on the Revised Trauma Score, the Injury Severity Score, and patient age. The mathematical form of the norms is

TABLE I
Revised Trauma Score variables

Glasgow Coma Scale	Systolic Blood Pressure (mm Hg)	Respiratory Rate (min)	Coded Value
13–15	>89	10–29	4
9–12	76–89	>29	3
6–8	50–75	6–9	2
4–5	1–49	1–5	1
3	0	0	0

the logistic function $P_S = 1/(1+e^{-6})$ in which P_S is patient survival probability, e is the base of the natural logarithm system, $b = b_0+b_1(RTS)+b_2(ISS)+b_3(AGE)$, RTS is the patient's Revised Trauma Score at emergency department admission, ISS is the Injury Severity Score, AGE = 0 for patients < 55 years and AGE = 1 for patients ≥55 years of age. The b's are regression weights (40).

MTOS norms were obtained for adult (≥15 years) patients with blunt injuries and for adult patients with penetrating injuries. Those norms were derived using data from confirmed consecutive patients from 51 institutions and included 15,754 patients with blunt injuries and 7,423 patients with penetrating injuries. Norm regression weights are given in Table II. Regression weights for adult (15–55 years) blunt-injured patients are also used for pediatric patients.

Quality Assurance and Outcome Evaluation Methods. MTOS utilizes TRISS norms in two evaluation methodologies, PRE and DEF. PRE (PREliminary outcome-based evaluation) (14) supports quality assurance activities. Figure 1 is a scatter diagram (called a PRE chart) for a patient set (e.g., blunt-injured patients, 15 to 55 years of age). Survivors and nonsurvivors are indicated by L's and D's respectively. Patients whose ISS-RTS coordinates are on the diagonal line (determined by setting b = 0 in the norm equation) are estimated to have a 0.50 survival probability. Coordinates above (below) the line have estimated survival probabilities less than (greater than) 0.50. Survivors (L's) above the line and nonsurvivors (D's) below it represent patients with mathematically unexpected outcomes perhaps worthy of physician scrutiny and peer review.

TABLE II
1987 MTOS outcome norms

	b_0	b_1 (RTS)	b_2 (ISS)	b_3 (AGE)
Blunt	−1.2470	0.9544	−0.0768	−1.9052
Penetrating	−0.6029	1.1430	−0.1516	−2.6676

DEF (an abbreviation for DEFinitive outcome-based evaluation) (18) is a statistical method for comparing the outcomes of two patient groups in this case, study (hospital) and baseline (norm) populations. In DEF, the statistic z compares the actual number of survivors (A) in a sample (hospital) to the number expected (E) for a set of patients with equivalent injury severities whose outcomes are predicted by a norm derived from baseline population data (21). z is the ratio (A-E)/S, where S is a scale factor that accounts for statistical variation. E equals $\sum P_i$, where P_i is the survival probability for the i^{th} patient in the study sample. P_i is computed using the outcome norm based on the data from the baseline population. S equals $\sqrt{\sum P_i}\,(1-P_i)$. z is positive or negative depending on whether the number of survivors in the study sample (A) is greater than or less than the number predicted by TRISS from the baseline data (E). Absolute values of z greater than 1.96 indicate that differences between A and E are statistically significant ($p < 0.05$).

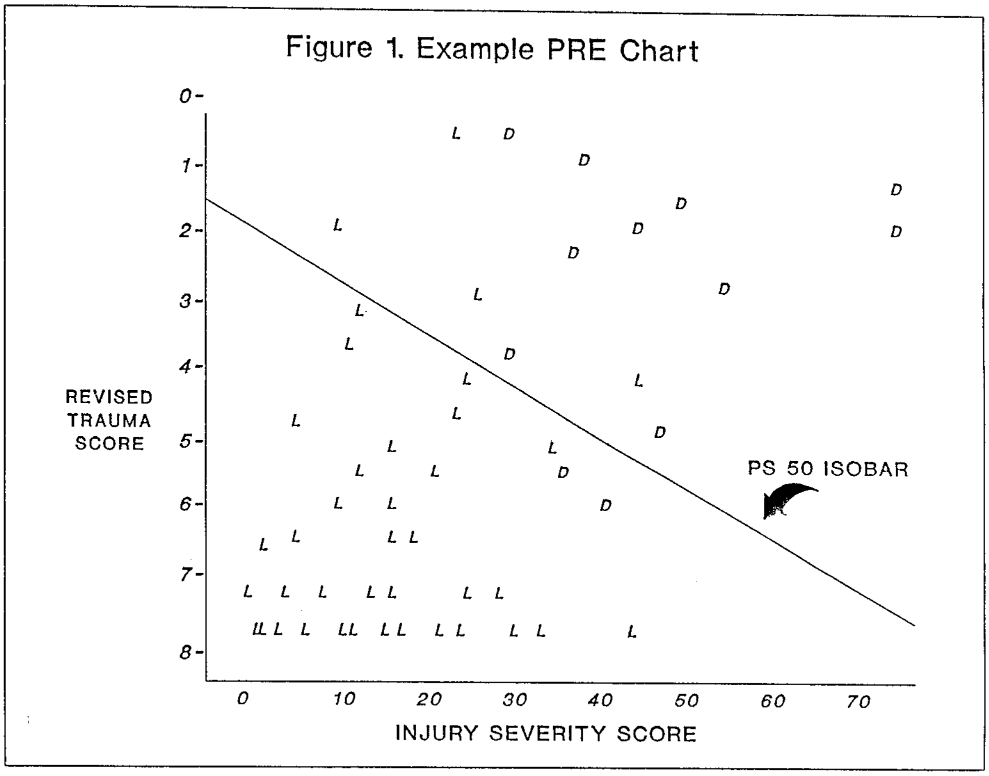

FIG. 1. The PRE chart supports quality assurance activities by indicating unexpected survivors (L's above the line) and unexpected nonsurvivors (D's below the line) that may be worthy of peer review.

Flora's z-score, developed for the outcome evaluation of burned patients, has been usefully applied in trauma as well. However, z has limitations. Nonsignificant scores can result from small sample sizes for which z has limited statistical power or from outcomes that are indistinguishable from the norm (35). For large samples, high (in absolute value) and statistically significant z-values can result from small and clinically insignificant departures from norm expectations. Thus, institutional performance cannot be inferred from the z-score magnitude. For institutions with significant z-scores, the statistic W is intended to describe the clinical or practical significance of differences between A and E

$$W = (A-E) / (N/100)$$

where A and E are as defined in z and N is the sample size. W is the average increase (or decrease) in the number of survivors per 100 patients treated compared with norm expectations. For example, an institutions with a statistically significant z-score and a W value of 3.6 for blunt-injured patients would have 3.6 more blunt-injured adult survivors per 100 such patients treated than would be expected from the MTOS norm. Institutions with nonsignificant z-scores have W values of 0.

Institution Confidentiality. Patient and institution are identified only by number on submitted data forms, thus assuring individual anonymity in the database. Before analysis, each institution was randomly assigned as "alias" identification number. Analysis packages containing data and results for each institution were assembled and mailed by persons not associated with processing of data to maintain institution confidentiality. The package defined the patient sample and outcome norms and suggested appropriate uses, interpretations, and limitations of the institution's results. Computer-generated reports provided each participant included:

1) a comparison of the demographics of its patients with those of the entire MTOS patient database;

2) a listing of its submitted data, including the ICD-9-CM and AIS codes assigned anatomic diagnoses;

3) PRE results identifying patients with mathematically unexpected outcomes perhaps worthy of peer review. To facilitate such reviews, patient identifying number, ISS, RTS, age, and TRISS-estimated survival probability are provided for such patients;

4) DEF outcome statistics;

5) a listing of data for patients excluded from PRE and DEF analyses because at least one of the variables needed to calculate survival probability was not available.

RESULTS

As noted previously, institutions could elect to submit data according to one of two sets of inclusion criteria. Results for *all* MTOS patients could therefore be inappropriate, especially for demographic, cause of injury, and length of stay statistics. Unless stated otherwise, results are from institutions submitting data on all admissions and all deaths due to trauma.

Etiology, Age, and Severity. Table III gives summary statistics for the entire MTOS database. (These results do not differ substantially from those for institutions submitting data on all deaths and all hospital admissions due to trauma.) Of MTOS patients 88.7% were suitable for analysis, having all data required for survival probability calculation: patient age, survival/death outcome, specification of blunt or penetrating injury, admission values of all RTS variables, and anatomic diagnoses sufficiently detailed to permit injury coding. The ratio of blunt-injured to penetrating-injured patients was nearly 4:1. The overall mortality rate was 9.0%. Motor vehicle-related injuries (motor vehicle, motorcy-

TABLE III
Summary MTOS data

	Number	Per Cent
Suitability for analysis		
Included	71,431	88.7
Excluded	9,113	11.3
Type of injury		
Blunt	63,555	78.9
Penetrating	16,989	21.1
Discharge status		
Live	73,282	91.0
Died	7,427	9.0
Unknown	15	0.0
Cause of injury		
Motor vehicle	27,973	34.7
Motorcycle	5,529	6.9
Pedestrian	6,077	7.5
Gunshot	8,045	10.0
Stabbing	7,655	9.5
Fall	13,263	16.5
Other	11,894	14.8
Unknown	108	0.1
Patient sex		
Male	57,231	71.1
Female	22,599	28.1
Unknown	714	0.9
Time to death		
<24 hours	4,337	59.8
≥24 hours	2,885	39.8
Unknown	25	0.3
Death patients		
Autopsy, CT scan, surgery	6,153	84.9
None	1,094	15.1

	Number	Per Cent	Mean	Std. Dev.
Patient age				
<15	8,713	10.8	7.5	4.3
≥15 and <55	59,179	73.5	28.9	9.6
≥55	12,451	15.5	70.8	10.6
Unknown	201	0.2	—	—
Revised Trauma Score on admission				
Defined	71,625	88.9	7.1	1.7
Incomplete	8,919	11.1	—	—
Injury Severity Score (85)				
Defined	80,538	100.0	12.8	11.3
Incomplete	6	0.0	—	—

cle, pedestrian) were most prevalent, accounting for 49.1% of submitted patients. Intentional injury, gunshot and stabbing, were the cause of injury in 19.5% of patients. Falls accounted for 16.5% of study patients. The data reaffirm that injury is a disease primarily of males, who represent nearly three fourths of MTOS patients. A majority (59.8%) of the more than 7,400 deaths occurred within 24 hours of injury. The clinical evaluation of injury descriptions for nonsurvivors was supplemented by autopsy, CT scan, or surgery in nearly 85% of the cases. Most patients were between 15 and 55 years old. The average RTS and ISS were 7.1 and 12.8, respectively. The frequency and per cent survival by RTS and ISS intervals are given in Tables IV and V.

There were 9,113 patients excluded from analyses. Of these, 7,707 (84.6%) had blunt injuries and 1,406 (15.4%) had penetrating injuries. Of excluded patients 97.9% (8,919) were missing one or more Revised Trauma Score variable values (16) (GCS 58%, RR 57%, SBP 25%) at

TABLE IV
Number of patients and per cent survival by Revised Trauma Score interval

RTS	No. of Patients	Per Cent Survival
0–<1	693	2.3
1–<2	82	11.0
2–<3	328	31.1
3–<4	249	46.6
4–<5	497	66.2
5–<6	1,035	85.4
6–<7	1,380	93.6
7–7.84	17,882	98.8

TABLE V
Number of patients and per cent survival by Injury Severity Score interval

ISS	Blunt-injured Patients			
	<55 Years		≥55 Years	
	Number	% Survival	Number	% Survival
1–8	7,171	99.8	966	98.1
9–15	4,639	97.9	1,291	95.8
16–24	2,451	88.9	436	77.5
25–40	1,506	76.3	263	55.1
41–49	273	59.7	43	23.3
50–74	152	34.2	21	14.3
75	119	13.4	28	0.0
Totals	16,311		3,048	

ISS	Penetrating-injured Patients			
	<55 Years		≥55 Years	
	Number	% Survival	Number	% Survival
1–8	2,153	99.9	95	100.0
9–15	1,028	98.3	47	93.6
16–24	752	90.0	43	69.8
25–40	798	58.9	65	26.2
41–49	72	34.7	5	20.0
50–74	43	39.5	4	25.0
75	63	12.7	8	0.0
Totals	4,909		267	

emergency department admission. Fifteen excluded patients had unknown discharge status and 201 had unknown ages. Six excluded patients had injury descriptions unsuitable for coding and, therefore, had undefined ISS values. The remaining 9,107 excluded patients had both significantly higher average ISS (14.8 vs. 12.5) and a significantly higher percentage of seriously injured patients (ISS ≥15) than included patients. Excluded patients had a significantly higher mortality rate (16.8%) than patients included in analyses (8.0%). Sex distributions of the two groups did not differ substantially. In the excluded group, there were more falls (23.4% vs. 15.6%) and fewer gunshot wounds (7.8% vs. 10.3%) and stab wounds (5.3% vs. 10.0%). The frequencies of deaths occurring less than and greater than 24 hours postinjury were comparable for the two groups, as were the sources of anatomic diagnoses.

Hospital Course. The average hospital stay for survivors (9.7 days) significantly exceeded that of nonsurvivors (4.6 days). However, the average ICU stay of nonsurvivors was slightly but significantly longer (3.3 vs. 2.0 days).

Figure 2 shows the per cent mortality, and average lengths of stay in the hospital and the ICU by cause of injury. Patients with gunshot wounds had the highest mortality rate (20.9%). Injured pedestrians had the second highest mortality rate (13.6%) and the longest average stays in the hospital (13.8 days) and in the ICU (3.1 days). Motor vehicle and motorcycle injuries resulted in death less frequently (7.7% and 8.7%) but had substantial lengths of stay in the hospital and the ICU.

Figure 3 shows the distribution of patient ages, associated mortality rates, and lengths of stay in the hospital and ICU. The average patient age was 32.4 years; 74.6% of patients were less than 40 years of age. A noticeable jump in mortality rate exists for patients 60 and older. Slight increases in hospital and ICU stays also accompany increasing age.

Figure 4 depicts the time from admission to death for patients taken directly from the injury scene to the hospital. The mortality rate for the subset of patients whose most severe head injury was AIS 3 or less (including those with no head injury) was 5.0%. The mortality rate for patients whose most severe head injury was AIS 4 or higher was 40.0%, and 57.8% of patients dying with severe head injury died within 24 hours of admission while 72.2% of deaths without serious head injury died within the same period. Deaths occurred most frequently within 1 hour of injury. Substantial numbers of deaths also occurred at about 1 day and ≥11 days postinjury. Trunkey noted a similar distribution of times to death (39): the trimodal distribution.

PRE and DEF Results. Table VI gives the numbers of mathematically unexpected survivors and deaths identified in the 1988 analysis, by patient category.

PRE identified 4.5% of the adult blunt-injured and 3.8% of the penetrating-injured patients as having un-

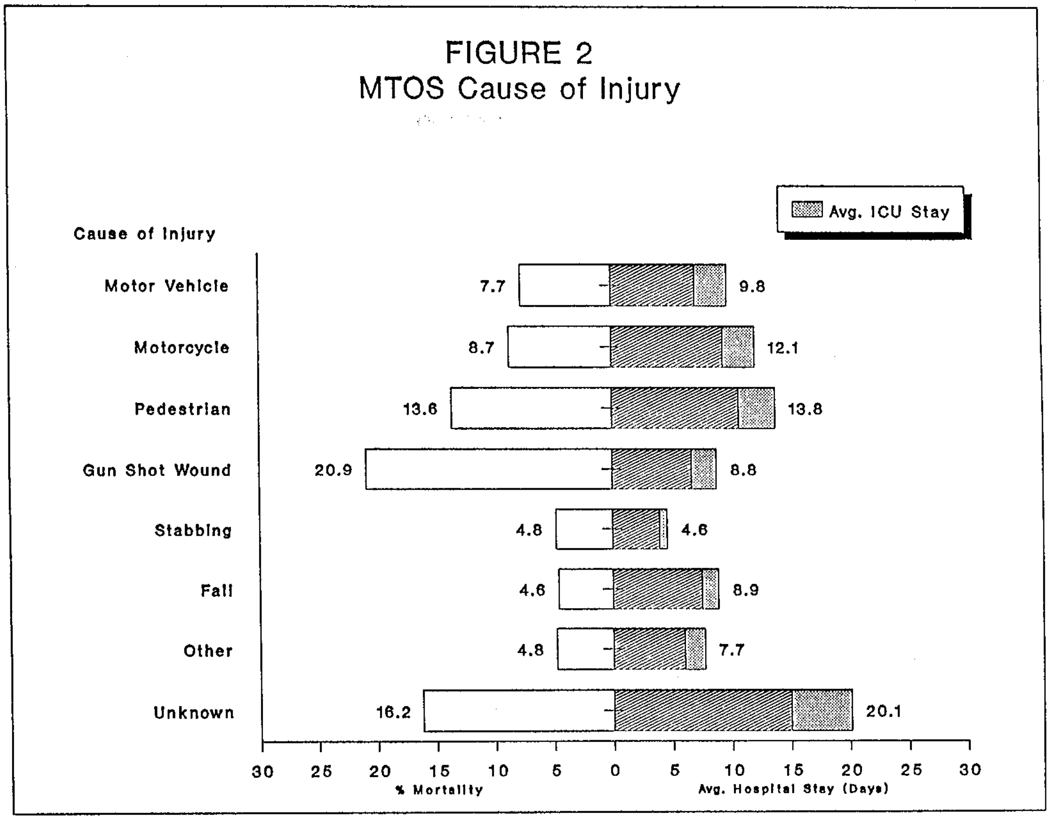

FIG. 2. Mortality and lengths of stay in the hospital and ICU shown by cause of injury.

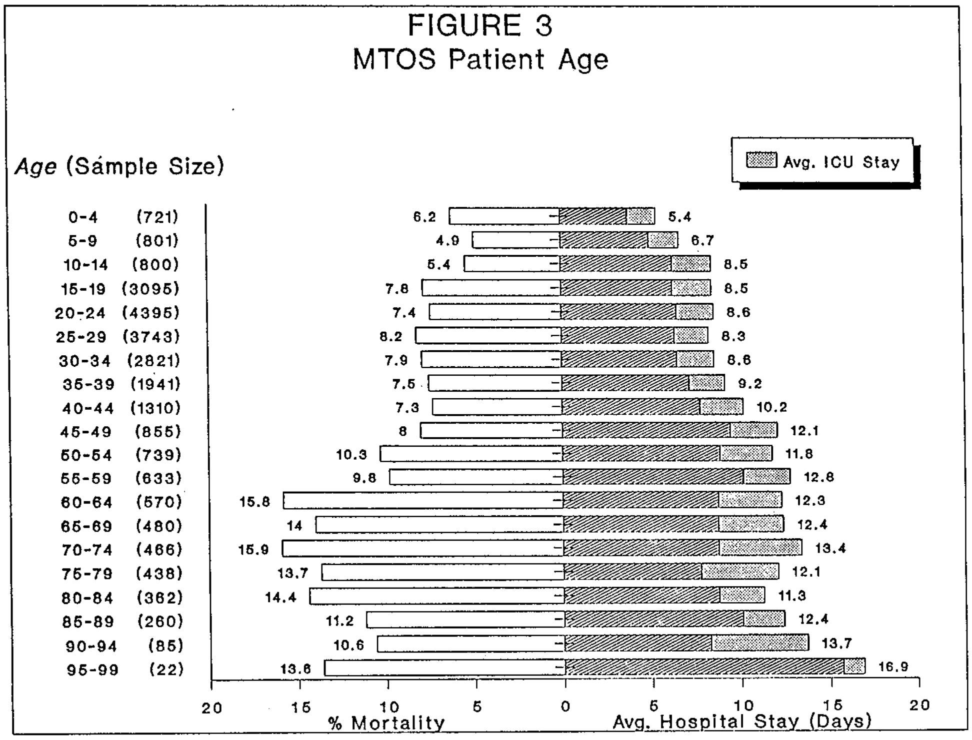

FIG. 3. Mortality and lengths of stay in the hospital and ICU shown by age.

expected outcomes. Most striking are those at the extremes of the survival probability scale. There were 155 unexpected survivors with TRISS survival probabilities less than 0.10 and 883 unexpected deaths with survival probabilities greater than 0.90. All of the 155 survivors had serious injuries and/or poor admission physiology and appear to be genuine therapeutic successes.

Most of the 883 unexpected deaths with high survival probability had excellent admission physiology. Two hundred forty-six (246) of those patients (27.8%) were

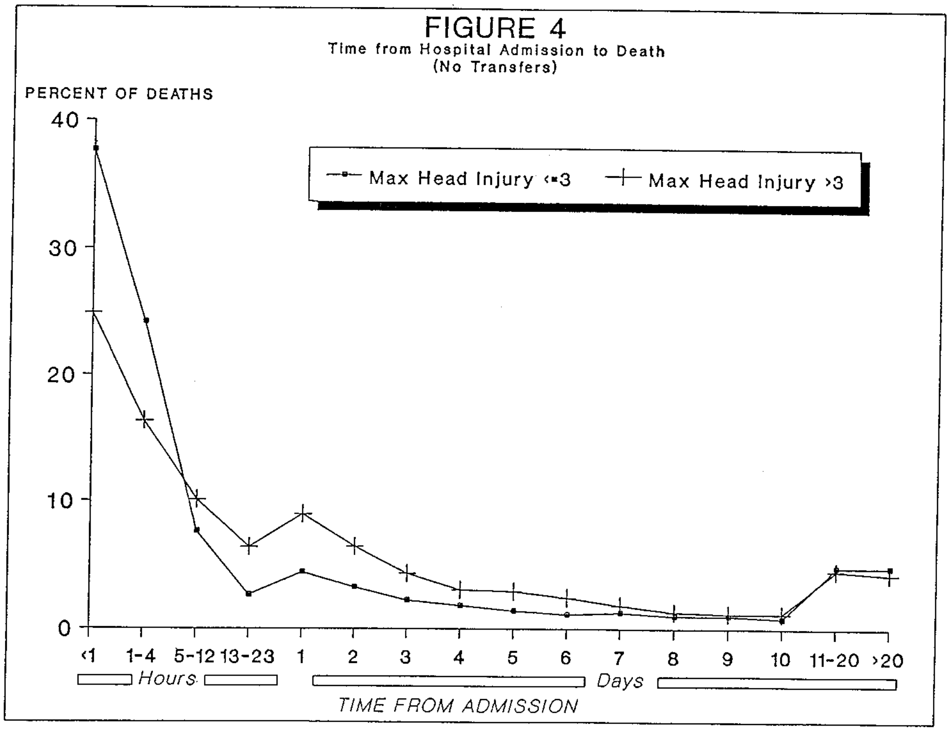

FIG. 4. Time lapses from admission to death for patients taken directly from the injury scene to the hospital shown by severity of head injury

TABLE VI
MTOS patients with unexpected outcomes

Patient Set	Number of Unexpected	
	Survivors	Nonsurvivors
Adult blunt injured	615	1,612
Adult penetrating injured	181	389
Pediatric patients	48	137
Totals	844	2,138

TABLE VII
DEF result summary: 1988 MTOS analysis

	Adult Patients		Pediatric Patients
	Blunt Injured	Penetrating Injured	
Number of Institutions	134	124	129
with z > 1.96	7	3	1
with z < −1.96	10	15	5
W-values*			
Maximum	+5.8	+3.5	+3.4
Minimum	−8.8	−5.5	−9.5

* Based on a sample of at least 25 patients.

more than 65 years old, although the elderly constituted only 10.1% of MTOS patients. One hundred thirty-nine (139) of the 883 patients (15.7%) had multiple AIS 4 or 5 injuries within the head/neck or thoracic regions and may be failures of the ISS and TRISS to accurately represent severity and to predict outcome.

Table VII summarizes DEF results by patient category. For each, there are institutions with significantly more (z > +1.96) and institutions with significantly fewer (z < −1.96) survivors than expected from outcome norms Ranges of W values for each patient set suggest a differ ence in the numbers of surviving patients of 9 to more than 13 per 100 treated. That is, for adult penetrating injured patients, one institution had 3.5 more survivors per 100 patients treated than expected from the norm while another had 5.5 fewer survivors per 100 patients than expected. The difference in those values is 9 survivors per 100 patients treated.

DISCUSSION

The Major Trauma Outcome Study is a step toward establishing a consistent and systematic national trauma database capable of responding to the need for injury information identified in *Injury in America.* MTOS data and analyses can be used to support injury research and provide individual hospitals and trauma centers with an objective, quantitative, and consistent basis for comparing the outcomes of their patients to those of their peers MTOS data can also be used to study trauma systems development and public policy.

MTOS is the largest database of descriptive contemporary injury information in the United States. However it is not population based. Participation is voluntary and participants are hospitals with staffs who may treat more than the average number of injured patients and who have a significant commitment to trauma care. The average 9.2-day length of hospital stay for all MTOS patients is higher than the 7-day figure reported by DHHS (23) for all injury admissions. The MTOS mortality rate of 9.0% suggests that MTOS is biased towards more severely injured patients, focusing on the population with potentially greater injury-related disability and deaths. Of the 3.6 million injured patients who are hospitalized annually, a rate of 17,000 per million population, the number of severely injured and hospitalized persons is no more than 1,000 per million per year. MTOS represents about a 7% sample of this latter group over the 5-year period during which data for this study were submitted.

The 139 institutions that have submitted data to MTOS through 1988 (Table VIII) include one half to two thirds of U.S. trauma centers (based on author estimates of 225 to 300 trauma centers nationally during this period) and are dispersed throughout the country. Participation varies but is increasing. Eighty (80) hospitals submitted data for approximately 33,000 patients during 1987, nearly three times the average number of submissions made in previous years. International interest has been evidenced by the submission of data for more than 4,000 Australian patients and by the participation of hospitals from the United Kingdom, which intends to establish its own national registry.

Evaluating Hospital Care. Government and public agencies are aware of wide variations in hospital and procedure utilization rates, practice patterns, and clinical results (41–44). This has resulted in a scrutiny of the quality of health care and an increasing demand for objective evaluation and institutional accountability. JCAHO stated that its accreditation criteria will shift from resource- and process-oriented measures to patient outcome-oriented measures of the results and, thus, possibly the quality of care rendered (27). Methods that identify cases worthy of critical professional scrutiny (peer review) by highlighting apparent instances of substandard care or outcomes are becoming increasingly important. A well conceived, consistently collected and analyzed database is essential to provide a credible basis for such initiatives.

The primary objectives of the PRE and DEF methods of MTOS are to identify, review, and learn from patients whose outcomes deviate from established norms. PRE supports quality assurance activities by identifying patients with statistically unexpected outcomes. Peer reviews of such patients may identify "preventable" and "possibly preventable" deaths and errors in technique, judgment, and diagnosis, and motivate change. Review of statistically unexpected survivors may identify patients whose care is worthy of future emulation. ACSCOT has also recommended audit filters to identify patients whose *process* of care is noteworthy (18). These filters include patients with ambulance scene times greater than 20 minutes, with emergency department time exceeding 2 hours when SBP on ED admission is less than 90 mm Hg, having more than twice the average ICU days for trauma patients at the specific hospital, and trauma patients returned to the operating room within 48 hours.

TABLE VIII
MTOS participants (through 1987)

Number of Institutions	Institution Type*
64	Level I
40	Level II
11	Level III
17	Pediatric specialty centers
7	Nondesignated hospitals
139	

* As reported by participating institutions.

Results of the MTOS DEF analysis indicated that 15% to 20% of participants had statistically significantly better or worse z-scores for adult patients with blunt injuries and for adult patients with penetrating injuries. Most of these hospitals had significantly fewer survivors than were expected from MTOS norms. They were encouraged to review their submitted data, injury descriptions, and assigned AIS severity scores and to critically review patients with unexpected outcomes. Only a single institution had significantly more pediatric survivors than expected. Plots of institutional z-scores by patient admission year are included in participant analysis packages and provide a visual comparison of patient outcomes with norm expectations over time.

PRE and DEF results provide MTOS participants with a starting point for self evaluation in quality assurance activities. However, important qualifiers exist. First, TRISS and other predictive models cannot control for excluded variables (e.g., preinjury health conditions) and do not explain all variation in patient outcome. Moreover, these models are most useful when applied to patient groups and are not intended to replace the input of qualified physicians in treatment decisions for individual patients. Second, only patients for whom all data elements needed for survival probability calculation are included in institution PRE and DEF analyses. Nearly 90% of MTOS patients qualified for analysis. However, an institution's excluded patients may strongly bias results. For example, nonsurvivors with minor to moderate injuries or survivors with moderate to serious injuries could substantially lower or raise z-scores. Thus, z and W scores and PRE results must be considered in the context of the injury severities and outcomes of patients excluded from analysis.

A third qualifier stems from limitations of injury severity indices. Limitations of the Trauma Score, the original physiologic component of TRISS, motivated the development of the Revised Trauma Score (12). The ISS is based on only the AIS Score for the most serious injury to any body region, considers all injuries with a given AIS severity level as equally serious regardless of body region, and admits a wide variety of injury combinations to an ISS value or interval cohort (4, 19). Concern regarding the ISS has motivated research for an index of anatomic injury severity that overcomes ISS limitations

(11). A several-valued characterization of anatomic injury is being evaluated that considers the numbers, severities, and locations of all patient injuries (16). When combined with a description of patient physiology on ED admission, the new characterization provides substantial improvements in the predictive reliability when compared with TRISS (9).

Evaluating EMS System Performance. Although organized systems of trauma care have been shown to reduce preventable deaths (8, 38, 45), they are supported by public health organizations in only eight states. In a national survey of U.S. trauma systems, only two states were found to have all trauma system components determined essential by the ACS and more than half the states had yet to initiate the process of trauma center designation (46). Widespread fundamental problems were cited, such as overdesignation of trauma centers, lack of triage criteria, and inadequate monitoring. Further, the current system of prospective reimbursement is not adjusted for injury severity and has been criticized for not adequately compensating hospitals treating the seriously injured (7, 26, 37). Many urban trauma centers, faced with inadequate funding, have been forced to cut back services or, as in Los Angeles, Miami, and Chicago, to close their facilities. Pending Congressional legislation, if passed, could mitigate these effects through an increase in federal funds for trauma centers/systems development (1, 25, 33). Until that time, EMS system managers must make planning and resource allocation decisions within constrained budgets.

MTOS data may be useful to EMS systems managers in health care planning and system evaluation. For example, MTOS results suggest the importance of early injury intervention if a substantial reduction in mortality is to be achieved (Fig. 4). For direct admissions, 72% of nonsurvivors without serious head injury and 58% of nonsurvivors with serious head injury die within 24 hours of injury. A 50% reduction in deaths occurring 10 days or more after injury would have roughly the same effect on mortality as a 7.5% reduction during the first 24 hours. Concentration of health care resources within the 24 hours immediately after injury would therefore be appropriate.

The MTOS elderly and pediatric populations have also been a focus for trauma system planning. In a comparative study (10) of elderly (≥65 years) MTOS patients and their younger counterparts whose data were submitted before 1987, older patients had a higher mortality rate (19.0% versus 9.8%), more frequent complications, and longer lengths of hospital and ICU stays. The increased mortality among older patients, apparent in Figure 3, is consistent with the lower average TRISS-estimated survival probability for that group (0.85 vs. 0.92 for younger patients) even though injury severities for the elderly and younger patients, as measured by average RTS and average ISS, were similar. The increased vulnerability of the elderly to injury has been frequently demonstrated (4, 6) and is represented in MTOS norms by the "b_3(AGE)" term that reduces survival probability for patients 55 years and older.

MTOS data have also enabled focused study of injured children, another group highly vulnerable to trauma. Through 1987, data for 8,713 pediatric trauma patients were submitted to MTOS, and 7,139 of those patients (81.9%) qualified for analysis. Ninety-three per cent (8,103) of pediatric patients had blunt injury (adults, 77.9%) and 66% were male (all MTOS, 71.1%). Although pediatric patients differed substantially from adults (e.g., distributions of causes of injury, mortality rate, lengths of hospital stay), MTOS norms for the adult population were found to be reliable outcome predictors (20). These results conflict with claims regarding the need for pediatric-specific injury scales (36).

Other uses of MTOS data for trauma systems managers and planners could include:

Comparing outcome among trauma centers. Major deviations from an acceptable standard of care could be used to influence the process of trauma center designation and verification.

Monitoring hospital and EMS systems to ensure continued provision of quality of care.

Evaluating the effects of new technology and the outcome of hospital and EMS system care.

Determining if relationships exist between trauma patient volume and institutional performance.

Comparing the outcomes of patients treated at various institution types, e.g., Level I and Level II trauma centers.

Monitoring the effect of trauma center/system cutbacks in staff and resources on patient outcome.

Determining the resources and costs required to rehabilitate injured patients, a problem that is not well defined in terms of incidence, outcome, and degrees of disability, particularly for head and spinal injury patients. MTOS is now collecting data on patient functional disability at discharge using elements of the Functional Independence Measure, developed by Hamilton et al. of the State University of New York at Buffalo (22)

SUMMARY

The importance of injury as a major American public health problem was cited by two landmark government reports, yet 2.5 million persons died between their publication. The MTOS is one effort in a renewed national focus on injury. It represents a substantial step toward creating a database that describes serious injury, assists in objective evaluations of care, quality assurance activities, and in trauma center/systems development. The database is incomplete, is not population-based, excludes patients with minor injuries, and contains no information on the long-term sequelae of injury. It does, however, contain information on the epidemiologic characteristics, hospital stays, and outcomes of serious individual and

combination injuries. As such, it provides a much needed database for injury research and a major and useful reference point for health planning and quality assurance. Further analyses will occur of the completed database of over 160,000 patients which closed to further submissions in December 1989.

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