ORIGINAL ARTICLE

Increased Survival Among Severe Trauma Patients

The Impact of a National Trauma System

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Hypothesis: The survival of severe trauma patients is affected by the implementation of a national trauma system, which brought about developments both at the hospital and prehospital levels during the past decade.

Design: A retrospective cohort study of all severely injured patients (Injury Severity Score >16) recorded in the Israeli National Trauma Registry at all level I trauma centers in Israel from January 1, 1997, to December 31, 2001. Inpatient death rates were examined overall and by subgroups.

Setting: The National Trauma Registry includes trauma (*International Statistical Classification of Diseases, 9th Revision, Clinical Modification* diagnosis codes 800-959) hospitalizations, patients who were transferred to or from other hospitals, and those who died in the emergency department. It excludes patients who were dead on arrival, discharged following treatment in the emergency department, and patients who do not fall into the definition of trauma.

Main Outcome Measure: Inpatient death.

Results: Seven thousand four hundred twenty-three severe trauma patients were recorded. Inpatient death rates decreased significantly from 21.6% in 1997 to 14.7% in 2001. The odds ratios of mortality in 1998 through 2001 vs 1997, adjusted for year, age, sex, penetrating injury, and severity of injury (Injury Severity Score >25), were 0.92, 0.89, 0.70, and 0.65, respectively, confirming the downward trend.

Conclusions: A steady significant reduction in the inpatient death rate of severe trauma patients hospitalized at all level I trauma centers in Israel between 1997 and 2001 was observed. Although a single factor that explains the reduction was not identified, it is evident that the establishment of the trauma system brought about a significant decrease in mortality. We believe that integrated cooperation of various components of the national trauma system in Israel across the years may explain the reduction.

Arch Surg. 2004;139:1231-1236

TRAUMA SYSTEMS IN ISRAEL have developed considerably in the last decade. A designated national committee delineated needs and standards and defined the fundamentals for trauma systems in the country.[1,2] These recommendations were approved and set into action by the Ministry of Health in the mid-1990s.

At the prehospital level, the emergency medical services (EMS) and the military medical evacuation units were upgraded with advanced life support capabilities. Courses for emergency medicine technicians–paramedics, advanced trauma life support (ATLS), and prehospital trauma life support were provided to a wide range of medical and paramedical personnel, and ATLS certification has become mandatory for all surgery residents. Ambulance dispatch centers were redistributed to reduce response time. At the hospital level, trauma services were set up, and emergency departments (EDs) were equipped with appropriate resources for management of complex trauma. Six medical centers were designated as level I trauma centers and 14 as regional trauma centers.

The Israel National Trauma Registry (ITR), established in 1995, provided the tools for continuous monitoring and quality assurance at the hospital[3] and national levels.[4] The Israel National Center for Trauma and Emergency Medicine Research, Tel-Hashomer, was formed to conduct, support, and promote research in the field of trauma. The National Trauma Council was appointed to advise the Ministry of Health on issues related to trauma. Advances in medical technology, experience gained by trauma centers because of the transfer of more severe patients to level I centers, and experience gained from mass casualty events and from peer-review

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Group Information: A list of the members of the Israel Trauma Group appears on page 1236.

Table 1. Israel National Trauma Registry Records of Patients With Severe Injury

	1997-2001	1997	1998	1999	2000	2001
No. of patients	63 044	10 398	12 133	12 390	13 604	14 519
No. of patients with ISS ≥16	7423	1178	1433	1364	1593	1855
Percentage of patients with ISS ≥16	11.8	11.7	11.8	11.0	11.8	12.8

Abbreviation: ISS, Injury Severity Score.

groups that meet regularly to discuss mortality have contributed to improvement in care. All these factors, along with the national awareness of trauma, have created an ambiance of a systematic upgrade in the resources and status of trauma care in Israel.

Previous studies have shown that following institution of a trauma system, an evident improvement in survival occurs.[5,6] The designation of regionalized level I trauma centers, where larger volumes of severe trauma patients are treated, leads to improved outcomes.[7] Following these reports, our objective was to examine the trends in survival of severe trauma patients in Israel following the implementation of a national trauma system. The unique contribution of this study is that unlike previous studies that dealt with regional or state data[5] with specific injury causes or injuries[6,8] or those that assumed that by drawing multiple such studies together[9] national conclusions could be drawn, the work we present reports actual national results, obtained directly from all level I trauma centers in the country.

METHODS

This retrospective study of severely injured patients included all 6 level I trauma centers in Israel. Data was collected for a 5-year period, from January 1997 through December 2001, from the ITR.

The ITR records all hospital trauma admissions, in-hospital deaths, and transfers to and from other acute care hospitals of patients arriving with a traumatic condition (*International Statistical Classification of Diseases, 9th Revision, Clinical Modification* codes 800-959). Included were patients with an Injury Severity Score (ISS)[10] of 16 or higher. Excluded were patients dead on arrival, patients discharged following treatment in the ED, and cases that did not fall within the formal definition of trauma, such as poisoning and suffocation. Data recorded in the registry include information on patient demographics, type and time of injury, and course of treatment and disposition. All variables were initially studied for each of the 6 hospitals separately, to detect variability in patient mix, which could affect inpatient mortality. Data were validated for consistency to examine whether significant changes to the population occurred during the study period. Subsequently, inpatient death rates were examined by subgroups. Subgrouping was based on variables that had previously been examined for quality and consistency. They included sex, age, severe torso injuries (Abbreviated Injury Scale [AIS] score ≥3), traumatic brain injuries, penetrating or nonpenetrating injury, postarrival time of inpatient death, mode of evacuation, external cause of injury, and more. Finally, a logistic regression, with in-hospital death as the dependent variable adjusted for age, sex, penetrating or nonpenetrating injury, ISS ≥ 25, and year of hospital admission, was performed. All statistical analyses were conducted using SAS statistical software (SAS Institute Inc, Cary, NC). Both proportions and mortality rates were compared by χ^2 test or by Mantel-Haenszel χ^2 test for linear trends. Continuous variables were compared by the Kruskal-Wallis test.

RESULTS

POPULATION

The ITR recorded 63 044 patients admitted to level I trauma centers between January 1997 and December 2001. Of them, 7423 (11.8%) had an ISS ≥16, and these composed the study population. The proportion of patients with an ISS ≥16, in the entire patient population captured in the ITR, did not decrease throughout the study period (11.7% in 1997; 12.8% in 2001), as presented in **Table 1**.

POPULATION CHARACTERISTICS

The demographic and clinical characteristics of the study group are detailed in **Table 2**. Forty-five percent of the study population had an ISS of 25 or higher, with a slight decrease of this proportion throughout the years, from 50% to 43% (P for trend <.001). The majority of the population was male (74%). The median age of the population was 28 years with no significant changes throughout the years. The proportion of patients admitted to the intensive care unit decreased slightly from 58% in 1997 to 54% in 2001, with no linear trend detected. The duration of stay in the intensive care unit did not change significantly and remained within a median of 4 days. Half of the patients had undergone surgical procedures in the operating room. There were slight, insignificant changes in the median length of hospital stay, which ranged from 8 to 9 days, and in the time spent in the ED, which ranged from 106 minutes to 120 minutes.

Traumatic brain injuries were suspected or diagnosed in 66% of the study population (range, 65%-68%). The proportion of penetrating injuries ranged from 5.5% to 12.3%, with a significant increase in 2001. Severe injuries to the torso (AIS score ≥3) were diagnosed in 43% of the patients. A large proportion of the patients sustained multiple injuries; 23% of the patients had more than 1 severe (AIS score ≥3) injury. Overall, most variables changed slightly during the years.

IN-HOSPITAL MORTALITY

Figure 1 depicts the nonadjusted in-hospital patient mortality rate of severe trauma patients by year. During the study period, in-hospital trauma deaths decreased from 21.6% to 14.7%.

Table 2. Characteristics of Patients With Injury Severity Scores of 16 or Higher in the Israel National Trauma Registry, 1997-2001*

	1997-2001 (n = 7423)	1997 (n = 1178)	1998 (n = 1433)	1999 (n = 1364)	2000 (n = 1593)	2001 (n = 1855)	*P* Value†
ISS ≥25	45	50	45	45	44	43	.005
Men	74	75	74	73	75	73	.38
Age, y							
Median	28	28	28	27	29	27	.29
Interquartile range	16-51	18-50	16-52	16-52	17-52	16-49	
0-17	27	24	27	29	26	29	
18-24	18	19	17	17	17	18	
25-64	39	41	39	38	39	37	
≥65	17	16	17	17	17	16	
Days in ICU	54	58	55	51	54	54	.007
Median	4	4	4	4	4	5	.40
Interquartile range	2-12	2-11	2-12	2-11	2-12	2-12	
Surgery required	50	48	50	49	50	50	.79
LOS, median, d	8	9	9	8	8	8	.22
Interquartile range	4-19	4-20	4-21	4-18	4-19	4-18	
Minutes in ED							
Median	111	120	106	107	110	116	.24
Interquartile range	46-207	50-214	50-195	47-206	46-206	43-219	
TBI	66	66	67	68	67	65	.48
Penetrating injury	7.8	6.3	6.2	5.5	7.3	12.3	.001
Severe torso injury, AIS score ≥3	43	45	40	43	44	43	.11
Single injury, AIS score ≥3	77	78	78	78	77	75	
Multiple injuries, AIS score ≥3	23	22	22	22	23	25	

Abbreviations: AIS, Abbreviated Injury Scale; ED, emergency department; ICU, intensive care unit; ISS, Injury Severity Score; LOS, length of hospital stay; TBI, traumatic brain injury.

*Values are expressed as percentages unless otherwise indicated. Sample sizes vary slightly because of item-level missing data.

†*P* value is based on χ^2 tests to check for differences between years.

The mortality rate in various subgroups was examined, as presented in **Table 3**. No major differences between hospitals were identified. Five of the 6 hospitals studied showed a linear decrease in mortality. One hospital showed a stable inpatient mortality rate. Hospitals were thus examined jointly. Mortality on the first day decreased from 8.8% to 6.6% (*P* for trend=.004) and later mortality, from 14.0% to 8.5% (*P* for trend <.001). In both severity groups, patients with an ISS of 16 to 24 and patients with an ISS of 25 or higher, a statistically significant decrease in the death rate was noted, from 9.0% to 5.4% (*P*=.01) and from 34.3% to 27.0% (*P* for trend <.001), respectively. The reduction in the trauma inpatient death rate was noted in both sexes, but it was more prominent in women (24.7% to 15.0%; *P* for trend <.001) compared with men (20.6% to 15.5%; *P* for trend <.001).

The death rate also decreased in most age groups, particularly in the young (aged 0-17 years); in patients who stayed in the intensive care unit (24.2% to 17.2%; *P* for trend <.001) and in those who did not (18.2% to 11.8%; *P* for trend <.001); and in patients who had surgery and those who did not. The presence of traumatic brain injury was associated with high mortality, but significant reduction in the death rate was recorded in patients with or without traumatic brain injury (Table 3). Penetrating injuries were also associated with higher inpatient mortality; however, mortality of both penetrating and nonpenetrating injuries decreased during the study period. Severe injuries to the torso also contributed to mortality; nevertheless, death rates were reduced from 20.1% in 1997 to 13.8% in 2001 for patients with no injuries to the torso (*P* for trend <.001) and from 23.4% to 15.8% (*P* for trend <.001) for patients who had severe torso injuries (AIS score≥3). Abbreviated Injury Scale scores of 3 or higher also resulted in fewer in-hospital deaths, both for patients with 1 or with multiple such severe injuries.

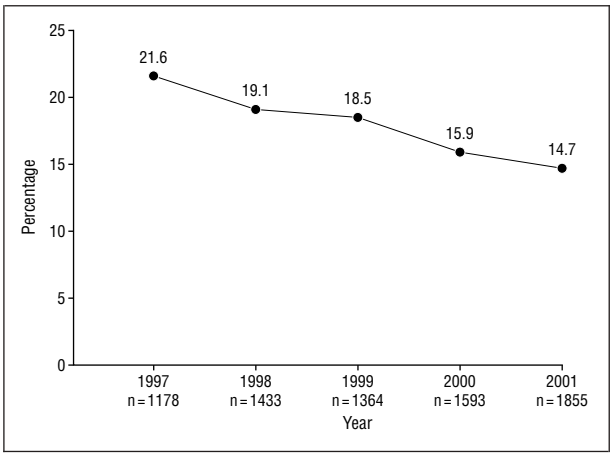

Figure 1. Inpatient mortality rate by year for severe trauma patients (Injury Severity Score≥16).

Multivariate analysis of in-hospital trauma deaths adjusted for age, sex, severity of injury (ISS≥25), penetrating injury, and year of hospital admission confirmed the downward trend. The adjusted odds ratio and 95% confidence intervals for the death rates, with

Table 3. In-Hospital Mortality of Patients With Injury Severity Scores of 16 or Higher by Subgroups*

	1997 (n = 117)	1998 (n = 1433)	1999 (n = 1364)	2000 (n = 1593)	2001 (n = 1855)	*P* Value for Linear Trend
Total inpatient mortality	21.6	19.1	18.5	15.9	14.7	<.001
First-day mortality	8.8	9.0	8.7	7.3	6.6	.004
Later mortality†	14.0	11.0	10.8	9.2	8.5	<.001
ISS						
16-24 (n = 4082)	9.0	6.0	5.7	5.4	5.4	.01
≥ 25 (n = 3341)	34.3	35.1	34.1	29.3	27.0	<.001
Sex						
Male (n = 5499)	20.6	18.6	18.2	15.6	15.5	<.001
Female (n = 1920)	24.7	20.7	19.6	16.8	15.0	<.001
Age, y						
0-17 (n = 1992)	13.6	11.8	10.1	7.5	7.9	.001
18-24 (n = 1286)	19.3	15.7	14.0	17.2	14.2	.24
25-64 (n = 2837)	19.2	17.5	20.1	14.2	13.6	.002
≥65 (n = 1223)	41.1	38.2	34.2	29.9	29.6	.001
ICU						
Yes (n = 4006)	24.2	20.8	21.3	17.2	17.2	<.001
No (n = 3397)	18.2	17.3	15.7	14.4	11.8	<.001
Operations/procedures						
Yes (n = 3679)	20.4	16.6	18.4	14.8	14.4	.002
No (n = 3744)	22.6	21.6	18.7	17.0	14.9	<.001
TBI						
Yes (n = 4925)	21.6	21.0	20.0	17.1	16.7	<.001
No (n = 2498)	21.5	15.3	15.5	13.4	11.0	<.001
Penetrating injury						
Yes (n = 581)	31.1	25.8	26.7	24.1	18.5	.02
No (n = 6832)	20.8	18.6	18.1	15.2	14.1	<.001
Severe torso injury, AIS score ≥ 3						
Yes (n = 3191)	23.4	21.4	19.6	19.2	15.8	<.001
No (n = 4232)	20.1	17.6	17.8	13.3	13.8	<.001
AIS score ≥ 3						
Single (n = 5586)	18.8	17.3	16.4	12.8	12.4	.001
Multiple (n = 1665)	32.4	26.9	26.9	26.6	23.2	.02
Multivariate analysis of inpatient mortality						
Adjusted odds ratio‡	1.0	0.92	0.89	0.70	0.65	
95% Confidence interval		0.74-1.13	0.71-1.10	0.56-0.87	0.53-0.80	

Abbreviations: AIS, Abbreviated Injury Score; ICU, intensive care unit; ISS, Injury Severity Score; TBI, traumatic brain injury.
*Values are expressed as percentages unless otherwise indicated.
†Proportion of first-day survivors.
‡Adjusted for age, sex, penetrating injury, and ISS ≥25.

1997 as reference, are presented in **Figure 2** and in Table 3.

COMMENT

The data presented describe significant improvement in the survival of severely injured patients in all level I trauma centers in Israel during a 5-year period following the establishment of a national trauma system. The trend of decreasing mortality has been observed in each hospital separately, in both patients with an ISS of 16 to 24 and those with an ISS of 25 or higher and in all age groups. The reduction in the death rate among the young was the highest, and their mortality was the lowest of all age groups. Elderly individuals, with the highest inpatient death rate of severe patients, also enjoyed a systematic significant decrease.

The first-day survival rate and the subsequent survival rate improved in patients who had undergone surgical procedures and in those who had not and in patients admitted to intensive care units and those who were not. A prominent change in the decrease in inpatient death on day 1 matches the model of Trunkey,[11] which places most deaths in the short early postinjury period, and therefore, this time provides the biggest opportunity for improvement of survival.

Mortality is an accepted marker of the quality of treatment in a trauma system. It is easy to measure, being one end point of treatment, and it is influenced by every link in the chain of treatment. However, the variability of case mix of trauma patients makes comparison among studies difficult. Some have gauged the overall death rate in the population, others have focused on patients with AIS scores of 3 or higher[8,12] or severe injuries (ISS≥16),[13] and few have concentrated on penetrating abdominal injuries or multisystem blunt trauma.[7] We focused only on severe trauma patients (ISS≥16), because this partly circumvents problems caused by the heterogeneity of patients and enables comparison with several other studies.[5,12,14]

The crude rate of inpatient mortality (5.4% for ISS≥16 and 27% for ISS≥25) concurs with the range described

by others.[12,14] The reduced risk of death of odds ratio = 0.65 found for the 5-year study period is similar to that reported by others: 0.65 in 8 years,[5] 0.70 for a 10-year period,[13] or 0.45 for 2000 compared with 1997.[15]

At the beginning of this study, emergency medical care and trauma care in Israel were in their infancy.[16] The scope of changes since the mid-1990s is huge. In the prehospital setting, between 1997 and today, the number of ambulance dispatch points has increased 2-fold (from 47 to 98 statewide). The number of advanced life support ambulances increased from 26 to 56; the number of paramedics more than tripled from 100 to 350 persons. Computerized control systems for ambulance dispatch were introduced, improving both evacuation and prehospital care.

At the hospital level, improvements include structural changes of all but 1 ED during the mid to late 1990s. These changes included matching the physical structure to specific ED needs. New EDs include shock trauma rooms with 2 to 6 beds, wider spaces, and new equipment. Furthermore, in 1998, emergency medicine was acknowledged and approved by the Department of Health as an academic subspecialty, and residents in this field began their training. As a result, the staff of ED today are much more qualified and better trained for providing emergency care. During this period, resuscitation courses have become compulsory for physicians and nurses, regardless of specialty, and refresher courses and drills are carried out periodically. Training for trauma care has also picked up during this period. Advanced trauma life support courses have become compulsory for all surgical specialties and subspecialties. A study of ATLS course graduates from various specialties reports that 67% of physicians found that the ATLS course enhanced their skills.[17] Additionally, surgeons and other specialists have been doing fellowships at high-volume trauma centers in the United States, returning to Israel with improved abilities and expertise. While trauma has not yet been certified as a subspecialty for training by the scientific committee, the Department of Health has defined the requirements of a trauma unit (a trauma director, a trauma coordinator, a trauma registry). Since 1997, the number of trauma units has increased from 8 to 11. Fellows and residents are doing elective rotations in these units. In terms of care provided, the designation of a trauma director provides a trauma patient with 1 entity who carries the overall responsibility for the care provided. This is particularly important for patients with multiple injuries requiring several subspecialties. What interventions are necessary and the timing of consultation of various subspecialties are among the important factors that may change the outcome of care. A national trauma registry, piloted from 1995 through 1996 at 5 trauma centers, began its full operation in 1997 with 8 hospitals (now 10). The registry provides tools for monitoring quality of care at both the hospital level and the national level. In addition, advancement in treatment protocols and patient management strategies that were well established in the literature made a contribution to increased survival during this period. Better availability of monitored beds improved

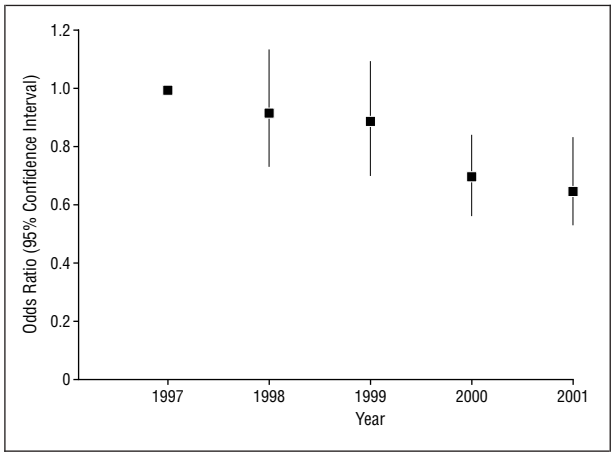

Figure 2. Multivariate analysis by inpatient death. The reference group was 1997; inpatient death was adjusted for year of hospital admission, age, sex, penetrating or nonpenetrating injury, and injury severity (Injury Severity Score ≥25).

care in intensive care units and may also have a part in saving lives following a traumatic injury.

The Israeli Trauma Society was established in 1993. This society provided training opportunities and a stage for better communications and sharing experiences between traumatologists around the country. During this period, peer review meetings with case presentations became a routine, contributing further to the improvement of care.

During the past years, changes have occurred in the protocol for receiving trauma patients at the hospital ED. Previously, a physician would be called after the patient arrived. Now, a trauma team awaits the patient in the trauma room.

The processes identified in Israel are very similar to those described elsewhere. During the first 4 years of operation of the South Australian trauma system, the Australian Trauma Registry recorded reduced risk of death of patients attending major trauma services.[15] Also, registry data of the first 4 years of implementation of a trauma system in the Finger Lakes region in New York indicated improved outcomes for patients with blunt trauma. This was attributed partly to changes in field triage and primarily to the direct transport of victims to designated trauma centers,[8] akin to the increase in transport of seriously injured patients to level I trauma centers in Oregon following the establishment of a state trauma system there.[5] The significant 14-year decline in trauma deaths in Nebraska was attributed to improvement in the statewide EMS system and in hospital care.[18] The adaptation of EMS to the treating capabilities of the trauma centers may change evacuation practices and destinations, to result in improved outcomes. These conclusions can be applied also to the present study, although it is difficult to separate the improvement to EMS from those of subsequent care and outcome.

Indeed, attempts to assess the contribution to the improved outcome of isolated factors, such as volume of patients in trauma centers[7,12,14] or the experience of the caregiver,[14] are controversial. Increased survival was found when the annual volume of a trauma center exceeded 650 high-risk patients,[7] a criterion easily met by the trauma centers included in the present study. The effect of

Israel Trauma Group

The Israel Trauma Group (ITG) is a study group that includes the heads of trauma units of hospitals participating in the Israeli National Trauma Registry. The ITG includes the authors Yoram Kluger, MD, Moshe Michaelson, MD, Avraham Rivkind, MD, Michael Stein, MD, and Ricardo Alficci, MD, Hillel Yafe Medical Center, Hadera, Israel; Igor Jeroukhimov, Assaf Harofe Medical Center, Zerifin, Israel; Yoram Klein, MD, Kaplan Medical Center, Rehovot, Israel; Gad Shaked, MD, Soroka Medical Center, Beer Sheba, Israel; and Daniel Simon, MD, Sheba Medical Center, Tel-Hashomer, Israel.

caregivers, however, is often obliterated by other aspects of hospitalization.[19]

Advancements in diagnosis and treatment can account for some of the reduction in mortality. One third of the decline in road accident mortality in England and Wales during past decades was attributed to advances in medical technology.[20,21] However, the mechanism by which technology affected the change in the probability of survival and the actual changes in survival rates for severe traffic-related injuries were not determined.[21]

Therefore, it is plausible that the improvement we have found resulted from the integration of all, or some, of the elements introduced by the comprehensive national trauma system. It is difficult to credit the trend of increased survival only to the formation of level I trauma centers, the training of professionals, the change in prehospital care, or the improved EMS facilities and performance. Most other studies have reached similar conclusions, and this further reinforces the importance of the synergetic contribution by all components and the accumulated experience.[13] Furthermore, this study offers a holistic view that examines all injury types at all level I trauma centers in the country, offering more of an overview of the trauma system. While some have suggested additional studies to explain the reduction of inpatient death, we feel that these are not genuinely necessary, especially since any change to 1 factor is bound to affect the others, and because the systemic approach was proven successful.

In conclusion, our findings indicate that a reduction in inpatient deaths of severe trauma patients followed the implementation of a national trauma system. Because this was examined by outcome, it is difficult to determine the relative contribution of individual components of care to this change, and the validity of such breakdown remains questionable, especially in light of the constant improvement seen since the establishment of an organized trauma system in Israel.

Accepted for Publication: July 8, 2004.
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