Outcome of hospitalized injured patients after institution of a trauma system in an urban area.

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Objective. - To determine if risk of death for hospitalized injured patients changes when an urban trauma system is implemented. Design. - An analysis of the risk of death in hospitalized injured patients in 1984 and 1985 (pretrauma system), 1986 and 1987 (early trauma system), and 1990 and 1991 (established trauma system) using hospital discharge abstract data. Setting. - A total of 18 acute care hospitals in the four-county area encompassing Portland, Ore. Patients. - A cohort of 70 350 hospitalized patients with at least one discharge diagnosis indicating injury. Main Outcome Measure. - Death during hospitalization. Results. - After the trauma system was established, 77% of patients in the region with an injury Severity Score (ISS) of 16 or greater were admitted to level I trauma centers. More than 72% of patients with an ISS less than 16 were hospitalized in nontrauma center's. Risk of death for injured patients hospitalized at level I trauma centers declined after the trauma system was established (odds ratio, 0.65; 95% confidence interval, 0.51 to 0.81). Patients who died in trauma centers after institution of the trauma system were younger and had more severe injuries, and the majority died within 1 day of admission, Whereas patients who died in nontrauma centers died a median of 5 days after admission. Conclusion. - Establishment of a trauma system shifted the more seriously injured patients to level I trauma centers, where there was a significant reduction in the adjusted death rate. (JAMA. 1994;271:1919-1924)

A trauma system for the treatment of the severely wounded or injured appears to have reduced the overall death rate for such patients in Portland, OR. Trauma systems are designed to have emergency medical technicians evaluate the severity of a patient's injury during triage. Patients with high injury severity scores are then taken only to designated high-level trauma centers. Patients with lower injury severity scores are taken to non-trauma centers. The trauma system implemented in Portland, OR, in 1986 has led to an increase in the number of patients admitted to high-level trauma centers. Those with high injury severity scores at high-level trauma centers have experienced improved survival rates, while the overall death rate at such centers has remained largely unchanged. However, the average survival time of the critically injured who died decreased, suggesting an increase in the severity of the injuries.

Regional trauma systems in large metropolitan areas are devised to transport severely injured patients to designated trauma centers where comprehensive care is immediately available. Retrospective studies of injured patients admitted to hospitals that are not designated trauma centers have reported that 20% to 40% of fatalities could have been prevented with optimal care.[1-3]

In 1986, in response to a law passed by the Oregon State legislature, a regional trauma system that included the four-county area surrounding Portland, Ore, was organized. An essential component of the trauma system was that emergency medical technicians should evaluate patients at the scene of injury using triage criteria. These criteria identified patients with severe life-threatening injuries who should be taken to trauma centers, where resources and personnel were committed to immediate treatment of injured patients. Five of the 18 acute care hospitals in the Portland area applied for trauma center designation and accepted trauma system patients during the initial phase of the system (1986 and 1987). During 1987, the trauma centers were inspected by the Oregon State Health Division, and two were designated as level I trauma centers. Beginning in May 1988, these two hospitals began functioning as the only designated trauma centers in the area.

To be effective, trauma systems must improve both the process and outcome of care. An important aspect of the process of care is whether severely injured patients are actually brought to trauma centers. The most important aspect of the outcome of care is whether such patients are more likely to survive after implementation of the system.

The overall impact of a trauma system on both of these measures should be examined. Previous studies of the effect of regional trauma systems have used data from trauma registries.[1,3,5] Trauma registries include information about patients who receive care in designated trauma centers but exclude severely injured patients who,

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perhaps inappropriately, are transported to and cared for in other hospitals. In this study, we used data from all hospitals in the region to examine both the pattern and outcome of care for hospitalized, injured patients. We tested the hypotheses that (1) introduction of the trauma system directed seriously injured patients to trauma centers and (2) implementation of a trauma system reduced mortality from serious injury.

METHODS

Definition of Trauma System

Our analysis focuses on an urban region that encompasses the four counties (Multnomah, Washington, Clackamas, and Columbia) that constitute metropolitan Portland and its suburbs. After institution of the trauma system in 1986, emergency medical technicians at the scene of injury were authorized to classify patients as either "trauma system patients" or others. A trauma system patient was identified using triage criteria that included physiological findings, anatomic injury, mechanism of injury, comorbid factors, and paramedics' discretion. Injured patients entered into the trauma system were transported to designated trauma centers. Injured patients not designated trauma system patients were transported to either trauma centers or nontrauma centers, often based on the patient's choice or insurance considerations.

Data Sources. - Most data for analyses were obtained from the Oregon Hospital Discharge Index (HDI). The HDI is compiled by the Oregon Hospital Association; the state of Oregon has oversight for the completeness and accuracy of the data. The following information is available in the HDI for each patient admitted to an acute care hospital in Oregon: date of birth, gender, admission and discharge dates, an identifying code for each hospital, up to five discharge diagnoses listed as International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)[6] codes, and disposition at discharge. Data from the HDI have been used in previous investigations by our group and other investigators.[7,8]

Other data sources were used to supplement or to audit the HDI data. First, all trauma-related deaths for the four-county region during the period of interest were computed using Oregon Vital Statistics data on deaths of residents due to unintended injury (E codes 800 through 949), suicide (950 through 959), homicide (960 through 978), and undetermined injury (980 through 989). These summary data combine nonhospital, emergency department, and inhospital deaths and allow comparison with the HDI data, which list only inhospital deaths. Second, the Oregon Fatal Accident Reporting System (FARS) was examined to determine the trend in traffic fatalities in the Portland area during the period of interest. The FARS reports on all motor vehicle-related deaths in the four-county region and divides traffic fatalities into dead at the scene and dead after transport to a hospital. Third, to examine the accuracy of the Injury Severity Score (ISS) assigned by the MacKenzie mapping program,[9] we linked data from the HDI with Trauma Registry (TR) data from our own institution. In the TR data, diagnostic codes and ISSs were assigned after detailed review of the patient chart by a trained nurse abstractor. Finally, when our audit revealed systematic inconsistencies, we asked personnel at the Oregon State Health Division and the Oregon Hospital Association for clarification.

Oregon Hospital Discharge Index Patients. - We attempted to identify all patients who were injured in the metropolitan region and survived to be admitted to local hospitals. First, we obtained from the HDI all admissions from 1984 through 1991 excluding 1988 and 1989 that had one of the following ICD-9-CM 9-CM codes in any field: 800 through 959, excluding 905 through 909 (late effects of injury), 930 through 939 (foreign bodies), and 958 (trauma complications).[10] Second, we identified all patients who were hospitalized in one of 18 hospitals in the four-county area. Third, we applied a deterministic matching procedure to identify and exclude transferred patients whose first hospitalization was outside this area. Patients consecutively admitted to two or more North Willamette hospitals were assigned to the first hospital, and final outcome was attributed to the first hospital. We have previously used the matching procedure and examined its performance for a subset of patients transferred to our institution.[8] Fourth, we identified admissions for rehabilitation by ICD-9-CM codes and excluded those admissions from analysis.

Hospital Designation. - The 18 acute care hospitals in the region were divided into three groups: group 1 (level I trauma centers) are the two level I trauma centers that functioned as such since January 1986; group 2 applicant trauma centers) are the three hospitals that were trauma centers during January 1986 to April 1988; and group 3 (nontrauma centers) are 13 other acute care hospitals that did not receive trauma system patients.

Injury Severity Scoring. - The ICD-9-CM 9-CM codes were converted to Abbreviated Injury Scale (AIS) scores using a computer program developed by MacKenzie et al based on the AIS version published in 1985.[9] The AIS scores range from 0 for no injury to 6 for a nonsurvivable injury. The ISSs were calculated from AIS scores using the standard formula.[9] For patients with multiple admissions

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to North Willamette District hospitals, the greatest ISS assigned was used. Some injuries cannot be given an AIS score by the MacKenzie program because nonspecific injury codes are used. The use of nonspecific injury codes has created difficulties in previous studies that have used administrative data sets.[11] In our data, 1% to 2% of patients each year had at least one body region with a nonspecific injury.

Analyses. - The goals of the analyses were (1) to examine where severely injured patients died after institution of the trauma system (decedent analysis) and (2) to examine whether survival of injured patients changed over time with institution of the trauma system (outcome analysis). All analyses were done with SAS, Version 6.07 (SAS Institute, Cary, NC), using PROC FREQ, PROC NPAR1WAY, PROC UNIVARIATE, and PROC LOGIST.

Decedent Analysis for this analysis, we compared patient characteristics and length of stay between the two designated trauma centers and the 16 other Portland area hospitals in 1990 and 1991. Variables for patient characteristics were defined as follows:

Age. - Patients were divided into three groups: children (aged 0 to 14 years), adults (aged 15 to 65 years), and the elderly (older than 65 years), based on age on date of injury.

Gender. - Patients were grouped by gender.

Comorbidity. - Preexisting conditions reported by Morris et al[10] as associated with death in injured patients were identified using ICD-9-CM codes listed in the discharge diagnoses. We defined patients with any of the following codes as having a preexisting condition: chronic obstructive pulmonary disease and associated conditions (ICD-9-CM codes 490 through 496), congenital coagulopathy (286 through 287, except 286.6 and 287.4), chronic liver disease and cirrhosis (571), and ischemic heart disease (410 through 414).

Severity. - Patients with an ISS of 1 through 15 were designated as having minor injuries, and patients with an ISS of 16 or greater were designated as having serious injuries. The accuracy of this classification was assessed by comparison of the ISSs calculated from the HDI data by the computer program with those calculated from TR data. Among patients assigned a minor injury score in the HDI, 91% were assigned a minor injury score in the TR. For those assigned a serious injury score in the HDI, 82% received a serious injury score in the TR.

Anatomic Injury Scores. - Each of the six regional AIS scores were examined separately.

Multiple Injuries. - A separate variable was constructed for patients with multiple injuries. Patients with AIS scores of 2 or greater in more than one of the six AIS body regions were defined as having multiple injuries.

Frequencies for designated trauma centers vs all other hospitals were compared using the [X.sup.2] statistic; the Wilcoxon Rank Sum Test was used to compare lengths of stay.

Outcome Analysis. - We used logistic regression to assess the effect of implementation of the trauma system on survival of hospitalized injured patients. The logistic regression model was developed using the change-in-estimate method of model building described by Greenland.12 Multicollinearity and fit of the models were assessed using the approach of Hosmer and Lemeshow.[13] The dependent variable in this analysis was death in the hospital. The patient characteristic variable described previously, as well as a variable for age-squared and six variables defined as the squares of each of the six regional AIS scores, were potential confounders in the model. The independent variable of interest in the analysis was the period of treatment with respect to implementation of the trauma system, defined as follows:

We compared three periods of 2 years' duration each: before the trauma system January 1984 through December 1985); the transition period January 1986 through December 1987), when patients entered into the trauma system were transported to one of five trauma centers; and after establishment of the current trauma system January 1990 through December 1991), when trauma system patients were transported to one of two level I trauma centers.

The final model for the risk of death included age, age-squared, gender, preexisting condition, and five of the six squared AIS terms (all except face). Compared with the ISS, the five separate AIS scores provided additional explanatory power ([R.sup.2]=.24 vs [R.sup.2]=.21). To test for trends that might have reflected changes in ICD-9-CM coding over time, we examined the performance of the model separately for each period. There was no noticeable loss or increase in explanatory power over time. Stratified analyses were performed for individual hospital groups divided according to trauma center designation and for patient groups divided according to severity of injury and age.

RESULTS

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Population and Trends in the District

During the three study periods, the number of injured patients admitted to the 18 acute care hospitals in the North Willamette District declined 13.3%, from 25 145 admitted in 1984 and 1985 to 21 806 admitted in 1990 and 1991. During the same period, there was an increase in the number of patients with severe injuries and the number of injured patients who died. Extremity injuries occurred most frequently (58%), followed by external (30%), head (15%), chest (10%), abdominal (8%), and facial injuries (7%). In 1990 and 1991, 77% of patients in the North Willamette region with an ISS of 16 or greater were admitted to level I trauma centers, whereas 72% of those with an ISS less than 16 were admitted to applicant and nontrauma centers.

Level I Trauma Centers

During the last study period, the number of injured patients hospitalized at the two level I trauma centers and the number of injured patients with an ISS of 16 or greater increased (Fig 1). In 1990 and 1991 these patients were more likely to be younger than 66 years and to have multiple injuries than in earlier periods. The total number of deaths per period increased, but the unadjusted death rate per period did not change significantly. Among those who died, the median time to death after admission decreased from 2 days to 1 day by 1990 and 1991 (Table 1).

[TABULAR DATA OMITTED]

Applicant Trauma Centers

The number of injured patients and the number of severely injured patients admitted to the three applicant trauma centers decreased during the last study period (Fig 1). In 1990 and 1991, when these hospitals were no longer trauma centers, elderly patients accounted for a greater portion of the patient population, and the frequency of patients with multiple injuries decreased from 10.2% to 3.2%. The death rate and the median time to death did not change significantly over time (Table 1).

Nontrauma Centers

During the last study period, the number of injured patients admitted to nontrauma centers declined 31% compared with the first study period, and the frequency of seriously injured patients also declined; by 1990 and 1991 only 3.2% of nontrauma center patients had an ISS of 16 or greater (Fig 1). Over time, the frequency of patients with multiple injuries decreased, and the percentage of patients older than 65 years increased. The death rate and the median time to death in the 13 hospitals did not change significantly with time (Table 1).

Characteristics of Decedents

in 1990 and 1991

To test our first hypothesis, that implementation of the trauma system shifted patients with life-threatening injuries to the trauma centers, we compared the characteristics of injured patients who died in the two trauma centers and 16 other hospitals in 1990 and 1991 (Table 2). Differences between those who died in trauma centers and the other hospitals paralleled differences in patients admitted to these hospitals. For example, in the other hospitals, deaths occurred more frequently among elderly patients and among patients with preexisting conditions. Only 14% of patients who died in the other hospitals were severely injured, whereas 86% of patients who died at trauma centers had serious injuries. Deaths were evenly distributed among men and women at the other hospitals, but men constituted 70% of the deaths at trauma centers. Only 3% of patients who died in the other hospitals had multiple injuries, whereas 50% of patients who died at trauma centers had multiple injuries. The distribution of injuries according to body region differed according to hospital type, with 64% of patients dying at other hospitals having an extremity injury compared with 24% of the patients dying at trauma centers. Among patients who died at trauma centers, the majority died within 1 day of admission, whereas at other hospitals the majority of deaths occurred 5 or more days after injury.

[TABULAR DATA OMITTED]

Outcome Analysis

To test the second hypothesis, that implementation of the trauma system improved outcome, we examined the adjusted risk of death for injured patients admitted to North Willamette District hospitals during the period of study (Table 3). Adjusted risk of death declined in 1990 and 1991 compared with the two earlier periods for injured patients admitted to level I trauma centers but remained unchanged in applicant and other hospitals. Adjusted risk of death among the entire cohort of hospitalized injured patients in the North Willamette District did not change over time. However, for all hospitalized injured patients in the region with an ISS of 16 or greater, the adjusted risk of death was lower in 1990 and 1991 compared with the two earlier periods (odds ratio [OR]=0.83; 95% confidence interval [CI], 0.70 to 0.99); for hospitalized injured children in the region, the adjusted risk of death was lower in 1990 and 1991 compared with the two earlier periods (OR=0.47;

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95% CI, 0.26 to 0.84).

[TABULAR DATA OMITTED]

Because patients with nonspecific injuries were admitted more frequently to level I hospitals and because these patients died more frequently than those with defined injuries, we repeated the analyses twice examining risk of death over time and included those with nonspecific injuries by assigning them an AIS score of either 1 or 6. In each case, the results remained the same as those presented in Table 3 (data not shown).

Population Death Rates

During the same period, 1984 through 1991, data obtained from Vital Statistics summarizing all trauma-related deaths in the region according to location of death showed that death rates overall and in each location (nonhospital, emergency department, and in-hospital) were lower in 1990 and 1991 compared with 1984 through 1987 (Fig 2).

Additional data on the subset of trauma deaths in the region caused by motor vehicle crashes published by FARS showed that the rate of death for patients who died after transport to a hospital decreased whereas the death rate at the trauma scene remained unchanged (Fig 3).

COMMENT

To our knowledge, this study is the first to use a comprehensive administrative data set to evaluate the impact of a new trauma system on the process and outcome of care for hospitalized injured patients. After implementation of the trauma system, severely injured patients in the region were more likely to be hospitalized in level I trauma centers and to survive their injuries. The effect is significant; the adjusted rate of mortality at the designated trauma centers was reduced by one third as compared with the pretrauma system rate.

Implementation of the trauma system in the North Willamette District began in 1986. By 1990 and 1991, 77% of patients in the district with severe injuries were admitted to the two level I trauma centers. The increase from 1984 through 1991 in the total number of patients with an ISS of 16 or greater admitted to the trauma centers was associated with a decline in the number of patients with an ISS of 16 or greater admitted to the other hospitals. Transfer of patients from outside the region also contributed to the increase in severely injured patients at level I trauma centers. In 1990 and 1991, 86% of patients who died with severe injuries were hospitalized in the trauma centers. This fact, along with examination of the profiles of patients dying in the trauma centers and the other hospitals, supports the conclusion that the trauma system has been successfully implemented. Introduction of the trauma system has shifted care of seriously injured patients at risk of imminent death to the trauma centers.

In this study, the risk of death from injury declined in the level I trauma centers but not in other hospitals. There are several potential explanations for why these differences occurred. First, the staff in trauma centers may have improved proficiency and developed better protocols for treating injured patients as the number of seriously injured patients admitted to the trauma centers increased from 580 in 1984 and 1985 to 1530 in 1990 and 1991. The critical workload required to achieve proficiency as a trauma center has been debated. Smith et al[5] analyzed the mortality rate of seven trauma centers and reported that when trauma centers' experience with seriously injured patients exceeded more than 600 patients every 2 years, mortality rates decreased. Other studies of deaths after surgical procedures have reported a favorable relationship between volume of a hospital's experience and outcome.[14] A second explanation for fewer deaths is that better prehospital care improved the condition of injured patients who met criteria for entry into the trauma system. A third explanation for reduced risk of death is that patients surviving at trauma centers would have had preventable deaths at nontrauma centers in the earlier years.[1,2,4] However, because the risk of death for injured patients admitted to the nontrauma center hospitals in the region did not significantly decline, the HDI data do not support this explanation.

We analyzed Vital Statistics and FARS data from the four-county North Willamette District to determine if there were changes in death rates due to injury from all causes and from motor vehicle crashes during the time that the trauma system was implemented. We analyzed these two sets of data because we reasoned that if the trauma system were to have a beneficial effect, there should be a change in rates of death. In both Vital Statistics and FARS data, a decline in death rate occurred among patients transported to the hospital. Explanations commonly offered in the lay press for this decline have been greater use of seat belts and other safety devices and better enforcement of traffic laws. However, the reduction in hospital death rates suggests that the improved survival rates among injured patients who were hospitalized for treatment contributed to this decline.

By using hospital discharge data, we analyzed all injured patients admitted to acute care hospitals in the North Willamette District. Previous studies examining the effectiveness of a trauma system have used only trauma

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registry data. These studies have the disadvantage of including only information on patients admitted to trauma centers.[3,4] The benefit of analyzing all injured patients hospitalized within the region is that influence of the trauma system on the entire community can be judged.[15,16] For example, in this study examination of the profile of injured patients who died in 1990 and 1991 demonstrated that the 284 patients who died in the trauma centers were young and had severe multiple injuries, and the majority died within 1 day of admission. However, a nearly equal number of injured patients died in hospitals that were not trauma centers. These were primarily elderly patients with an extremity region injury who died after 5 or more days of hospitalization.

A limitation of the data used in this study is that discharge abstracts do not include pertinent physiological and diagnostic information.[17] previous studies have shown that, when such information is available, it can correct under-adjustment of the risk of the sickest or most severely injured patients.[18] This Limitation makes it difficult to directly compare adjusted outcomes among hospitals that admit different patient populations. Limitations in risk adjustment would not readily account for the observed trends over time within each class of hospital. In our analysis, we did not attempt to compare risk-adjusted outcomes of trauma centers with those of other hospitals; instead, we compared outcomes over time within each class of hospital. We observed that the adjusted OR for death declined in the level I trauma centers even though the proportion of severely injured patients admitted to these centers increased over time.

Another limitation is that discharge data do not include injured patients who died during transport, in the emergency department, or after discharge from the hospital.[10] Analysis of emergency department deaths is important, because a compelling argument in favor of a regional trauma system is the preventable and rapid demise of injured patients brought to hospitals that were unprepared to promptly and correctly treat these patients.[2] Analysis of the HDI data is inadequate for study of emergency department preventable deaths. These patients would not have been admitted and thus could not be in the HDI database. According to Vital Statistics data, the death rate for injured patients in emergency departments for the region did decline after the trauma system was implemented. With the decline in death rate among seriously injured hospitalized patients and with fewer emergency department deaths, the composite information supports the conclusion that the risk of death declined for trauma patients.

In future analyses of the effect of a trauma system on the care of injured patients within a targeted region, we propose that thresholds should be determined regarding distribution of patients who die in trauma centers and nontrauma centers. For example, what fraction of pediatric trauma deaths occurring at a trauma center is considered acceptable? Was it appropriate that in this study 14% of patients who died in hospitals other than trauma centers had severe injuries? What is an acceptable death rate in the first 24 hours for patients not admitted to trauma centers? Using discharge data to determine the distribution of deaths from injury between trauma centers and nontrauma centers within a community may be a useful tool to assess whether a trauma system is fully operational.

Implementation of a trauma system in the North Willamette District has been successful. Seriously injured patients were primarily admitted to the trauma centers. A large proportion of hospitalized patients with minor injuries were admitted to nontrauma centers. The trauma system reduced the risk of death for seriously injured hospitalized patients in the region after 1986 and 1987 when the majority of these patients were admitted to two level I trauma centers. Further investigation is needed to determine acceptable thresholds for injury-related death rates in nontrauma centers when a community has a trauma system.

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