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Ten-Year Trend in Survival and Resource Utilization at a Level I Trauma Center

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Objective

To determine the impact of increasing trauma center experience over time on survival and resource utilization.

Methods

The authors studied a retrospective cohort at a single level I trauma center over a 10-year period, from 1986 to 1995. Patients included all hospital admissions and emergency department deaths. The main outcome measures were the case-fatality rate adjusted for injury severity, hospital length of stay, and costs.

Results

A total of 25,979 patients were admitted or died. The number of patients per year increased, from 2063 in 1986 to 3313 in 1995. The proportion of patients transferred from another institution increased from 16.2% to 34.4%. Although mean length of stay declined by 28.4%, from 9.5 to 6.8 days, costs increased by 16.7%, from $14,174 to $16,547. The use of specific radiologic investigations increased; the frequency of operative procedures either remained unchanged (craniotomy, fracture fixation) or decreased (celiotomy). After adjusting for injury severity and demographic factors, the mortality rate decreased over 10 years. The improvement in survival was confined to patients with an injury severity score ≥16.

Conclusion

Over a 10-year period, the case-fatality rate declined in patients with severe injuries. Overall acute care costs increased, partially because of the increased use of radiologic investigations. Even in otherwise established trauma centers, increasing cumulative experience results in improved survival rates in the most severely injured patients. These data suggest that experience contributes to a decrease in mortality rate after severe trauma and that developing trauma systems should consider this factor and limit the number of designated centers to maximize cumulative experience at individual centers.

An organized approach and commitment to trauma care have been credited with decreasing trauma-related fatalities.[1-6] Despite different study designs, population samples, and evaluation methods, with few exceptions studies have demonstrated the benefits of trauma center care. As a result, recommendations for the establishment of organized trauma systems have been developed and subsequently implemented in some regions. These recommendations address the process of trauma system development, the optimal structure of the system, and the ongoing evaluation of care provided within the system.[7]

However, it is disconcerting that trauma system development has not been universal or rapid, and that few regions have incorporated all recommended components of an inclusive trauma system.[8,9] Once established, trauma centers and trauma systems were found to be costly and difficult to support because of the extent to which trauma care is uncompensated.[10,11] It has been reported that care provided at a trauma center is more costly than care at other centers.[12] Such information may not be interpreted in favor of organized trauma systems, because hospitals, regions, and governmental agencies must balance the cost effectiveness of trauma care with other—often equally effective and equally costly—health care services. Trauma centers and systems must determine whether the costs associated with the establishment and maintenance of accredited trauma centers can be justified. It will be important to determine whether the highest level of trauma care has provided an increased survival benefit and whether trauma centers warrant contin-

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ued support to maintain a high volume and level of expertise at these centers.

Given these issues, the purpose of this study was to determine whether the evolution of a regional trauma center over 10 years led to a measurable survival benefit in injury victims. We sought to determine what changes in the practice of trauma care may have had an impact on the mortality rate for specific injuries and what impact these changes had on resource utilization over the same period.

METHODS

Study Institution and Region

Located in King County, Washington, Harborview Medical Center has functioned as the regional referral and tertiary trauma center for >10 years. By virtue of its relationship with the county, local emergency medical service systems, and the other institutions in the region, there has been little shift of major trauma patients among institutions in response to political or other initiatives. The institution provides all aspects of major trauma care and is a leading institution in many aspects of emergency medical services in the region. Over the study period, Washington state began a process of evaluating the trauma care in the entire state, drafting and implementing legislation aimed at establishing a statewide regional trauma system. This began with the establishment of a trauma steering committee by legislation in 1988. As part of this evolving plan, Harborview Medical Center was granted level I trauma center designation by the state of Washington in 1993.

Data Source and Description

All data for this investigation were abstracted from the institutional trauma registry, which has been maintained since July 1, 1985. Clinical data were abstracted directly from the patient record and entered into the registry by dedicated registrars. Financial data were obtained from the hospital finance department. All patients admitted between January 1, 1986, and December 31, 1995, were included in this analysis. Data abstracted included demographic features, including age and gender; measures of injury severity, including the abbreviated injury scale (AIS) score and the injury severity score (ISS); and whether the patient was admitted from the scene or transferred from a referring institution. Data regarding the use of computed tomography (CT), angiography, and operative interventions were also obtained. Hospital length of stay (LOS) and costs were examined in addition to survival as objective outcomes over the study period. Hospital costs were determined from charges using the institutional cost/charge ratio of 0.70. All costs were inflated to 1995 dollars using the yearly percentage cost increases for the institution.

Data Analysis

All statistical comparisons are based on data from the entire 10-year study period. Unless otherwise indicated, all analyses are based on linear trends over the 10-year period. Crude comparisons are based on the chi square test for trend and simple linear regression for categorical and continuous data, respectively.

The effect of multiple factors on survival, including year of admission, was examined using logistic regression. Variables included in the final model estimating survival included those that independently predict survival (based on $p < 0.05$) and those that alter the relation between survival and year. When the relation between survival and admission year was not the same for different levels of a variable (*i.e.*, a statistically significant interaction existed), subgroup analyses were performed to define the survival–year relationship. The adjusted odds ratio (OR) was used to estimate the relative risk of death for each variable and is presented in association with the 95% confidence interval (CI). For the purpose of this investigation, severely injured patients were defined as those with an ISS ≥16.[5]

Resource utilization is represented by hospital LOS, costs, and the number of patients undergoing one or more of the following operative or radiologic procedures: craniotomy (excluding placement of intracranial pressure monitor), surgical fixation of an osseous fracture, celiotomy, thoracic or pelvic angiography, and CT of the head or abdomen. Trends in the use of these resources were examined. Comparisons were made using simple linear regression for continuous data (costs, LOS) and the chi square test for trend for categorical data (radiologic investigations and operative procedures). Multiple linear regression was used to control for the effects of multiple factors on cost and LOS over time.

RESULTS

Over the 10-year period, 25,975 patients were admitted to the trauma center or died in the emergency department (ED). Mean age was 34.2 years, and 4474 (17.6%) were injured by penetrating mechanisms. A total of 2076 (8.0%) died, and 555 (26.7%) deaths occurred in the ED. Injury scoring for ED deaths was not done, and these patients are excluded from final analyses of resource utilization and adjusted survival. Of the remaining 25,420 patients, 52 had incomplete injury or cost data, leaving 25,368 patients for final analyses of adjusted survival and costs. Mean costs, LOS, and ISS were $15,980, 8.4 days, and 11.6. Overall, 7681 (30.2%) were severely injured (ISS ≥16), and 6601 (25.9%) were transferred after initially being seen at an outside institution. Severely injured patients (ISS ≥16) admitted directly from the injury scene had an overall mortality rate of 19.1%. Less severely injured patients admitted directly from the scene had the lowest overall mortality rate of 0.9%. Transferred patients were between these survival extremes (Fig. 1).

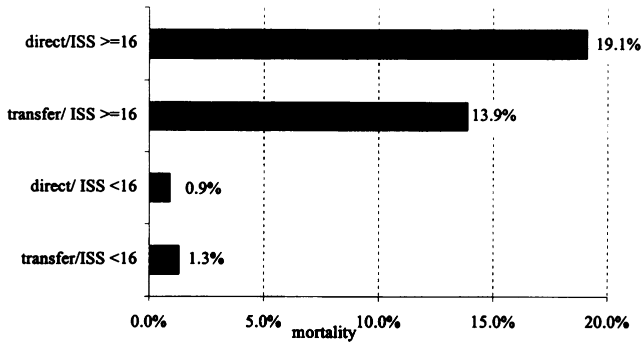

Figure 1. Fatality rate according to ISS and transfer status.

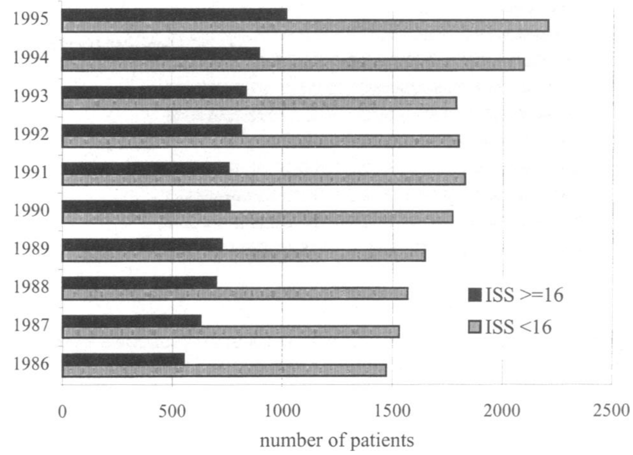

Figure 2. Yearly number of admissions according to ISS.

General demographic trends over the 10 years are presented in Table 1. In 1986, there were a total of 2023 trauma admissions, increasing to 3272 in 1995. The proportion transferred from an outside institution increased from 16.2% to 34.4% (chi square = 246.8, $p < 0.001$). The frequency of severe chest injuries (AIS $\geq$3) increased from 293 (14.5%) to 535 (16.6%), and the frequency of severe head injuries (AIS $\geq$3) rose from 439 (21.7%) to 858 (26.6%). As a result, the proportion of patients with injury severity scores $\geq$16 increased over the 10 years (Fig. 2).

Overall, 1050 (50.6%) deaths occurred in the intensive care unit, 555 (26.7%) in the ED, and 298 (14.4%) in the operating room. One hundred seventy-three (8.3%) patients died while on a general ward. The frequency of ED deaths was lowest in 1995 (18.2%) and highest in 1992 (36.3%), without a trend over the study period ($p = 0.55$; Fig. 3). The analyses that follow exclude ED deaths because injury scoring and resource utilization information was not collected for these patients.

Resource utilization changed over the study period. Mean length of stay declined from 9.5 days in 1986 to 6.7 days in 1995. In contrast, hospital costs (1995 dollars) increased, from $14,174 in 1986 to $16,547 in 1995 ($p < 0.001$ for both cost and LOS). After adjusting for age, mechanism of injury, regional injury severity (AIS scores), survival, and transfer from another institution, costs increased and LOS decreased over 10 years ($p < 0.001$ for both cost and LOS comparisons).

The use of specific radiologic investigations increased over time, with one exception. The use of abdominal CT peaked at 283 (10.8%) in 1992 and subsequently declined to 202 (6.2%) in 1995 (Table 2). The number of patients undergoing various operative interventions either remained unchanged or decreased. The use of operative fracture fixation and craniotomy fluctuated but did not change significantly. The proportion of patients undergoing celiotomy declined from 11.6% to 8.2% (Table 3).

The reduction in celiotomies was limited to patients with blunt injuries to the liver or spleen, where the rate decreased from 95.1% (58/61 patients) in 1986 to 67.4% (58/86 patients) in 1995. The increase in the nonoperative management of liver and spleen injuries, while using abdominal CT with an increased frequency, was associated with a reduc-

Table 1. DEMOGRAPHIC FEATURES*

Admission Year	Number of Admissions	Mean Age (years)	Mechanism (% blunt)	Transfer	ISS (mean)	Mean LOS (days)	Costs (mean)
1986	2023	34	80.5%	328 (16.2%)	11.2	9.5	$14,174
1987	2156	33	81.6%	406 (18.8%)	11.6	9.1	$13,935
1988	2266	33	82.0%	511 (22.6%)	11.9	9.9	$15,047
1989	2369	33	83.1%	548 (23.1%)	11.7	9.1	$14,171
1990	2530	34	82.6%	588 (23.2%)	11.7	8.8	$15,784
1991	2582	34	82.6%	617 (23.9%)	11.2	8.7	$16,902
1992	2612	34	83.2%	705 (27.0%)	11.6	8.4	$17,400
1993	2622	35	81.7%	867 (31.8%)	11.6	7.7	$16,764
1994	2987	35	82.0%	906 (30.3%)	11.3	7.1	$17,885
1995	3221	34	83.8%	1125 (34.4%)	12.0	6.7	$16,547

* Excluding 555 emergency department deaths.

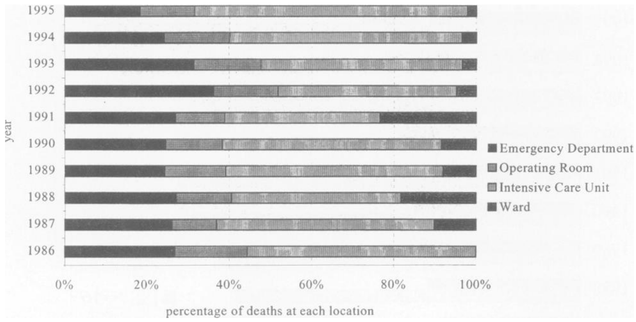

Figure 3. Location of death for 2081 fatalities, expressed as a percentage of total deaths for each year.

tion in the LOS and no change in costs. After adjusting for the effects of overall injury severity (ISS), hospital LOS decreased significantly for the 600 patients with either liver or spleen injuries ($p = 0.015$), and adjusted costs remained unchanged ($p = 0.72$).

Over 10 years, 1673 (6.6%) patients were admitted with pelvic fractures, the frequency of which increased from 5.3% in 1986 to 7.9% in 1995; the overall case-fatality rate was 9.2%. The use of pelvic angiography increased over time in patients with pelvic fractures but did not appear to contribute to an improvement in survival. Femur fractures were present in 2076 (8.6%) patients; this injury did not change in frequency over the study period and had a case-fatality rate of 7.3%. Trends in cost and LOS were not different for patients with or without femur fractures.

For the 25,368 patients who survived beyond the ED and had complete data available, the overall mortality rate was 6.0%, lowest in 1986 (5.4%) and highest in 1988 (6.8%). The adjusted mortality rate decreased significantly over the study period. The most important contributors to mortality rate were age; mechanism of injury; severity of injury to the chest, abdomen, or head; admission directly from the scene or transfer from another institution; and year of admission. However, the change in mortality rate with time was not the same for patients with severe injuries (ISS ≥16) as for those with less severe injuries. As a result, the study sample was divided according to whether the ISS was <16 or ≥16, and these analyses are presented below.

Controlling for the same factors as in the overall analysis, the yearly reduction in the case-fatality rate remained in the patients with ISS ≥16 (OR 1.04; 95% CI 1.02, 1.06) but not for patients with ISS <16 (OR 0.98; 95% CI 0.93, 1.03). Individual risk factors, adjusted ORs, and 95% CIs are presented in Table 4. These results indicate that the relative risk of survival increased (*i.e.*, risk of death decreased) by a factor of 1.04/year in patients with an ISS ≥16.

Table 2. RADIOLOGIC INVESTIGATIONS (1987–1995)

Year	Cranial CT	Abdominal CT	Thoracic Angiography	Pelvic Angiography
1987	620 (28.8%)	24 (1.1%)	69 (3.2%)	16 (0.7%)
1988	871 (38.4%)	35 (1.5%)	105 (4.6%)	15 (0.7%)
1989	1054 (44.5%)	139 (5.9%)	137 (5.8%)	27 (1.1%)
1990	930 (36.8%)	214 (8.5%)	159 (6.3%)	29 (1.1%)
1991	1114 (43.1%)	245 (9.5%)	136 (5.3%)	14 (0.5%)
1992	1179 (45.1%)	283 (10.8%)	151 (5.8%)	17 (0.7%)
1993	1265 (48.2%)	209 (8.0%)	197 (7.5%)	27 (1.0%)
1994	1308 (43.8%)	170 (5.7%)	308 (10.3%)	51 (1.7%)
1995	1594 (48.7%)	202 (6.2%)	301 (9.2%)	74 (2.3%)

Table 3. OPERATIVE PROCEDURES (1986–1995)

	Operative Procedures		
Year	Fracture Fixation	Craniotomy	Laparotomy
1986	351 (17.4%)	76 (3.8%)	235 (11.6%)
1987	367 (17.0%)	103 (4.8%)	262 (12.2%)
1988	401 (17.7%)	102 (4.5%)	257 (11.3%)
1989	431 (18.2%)	109 (4.6%)	239 (10.1%)
1990	481 (19.0%)	76 (3.0%)	233 (9.2%)
1991	494 (19.1%)	113 (4.4%)	244 (9.4%)
1992	497 (19.0%)	106 (4.1%)	257 (9.8%)
1993	521 (19.9%)	105 (4.0%)	263 (10.0%)
1994	547 (18.3%)	120 (4.0%)	245 (8.2%)
1995	579 (17.7%)	133 (4.1%)	267 (8.2%)

Table 4. ADJUSTED ODDS RATIOS FOR SURVIVAL

Risk Factor*	Adjusted Odds Ratio	95% Confidence Interval
	17,684 Patients with ISS <16	
Year of admission	0.98	0.9, 1.03
Age	0.94	0.93, 0.95
Abdominal AIS score	0.57	0.48, 0.67
Chest AIS score	0.59	0.52, 0.67
Head AIS score	0.74	0.63, 0.86
Mechanism**	2.73	1.86, 4.02
Transfer status***	1.48	1.02, 2.14
	7,678 Patients with ISS ≥16	
Year of admission	1.04	1.02, 1.06
Age	0.97	0.96, 0.98
Abdominal AIS score	0.71	0.68, 0.75
Chest AIS score	0.84	0.81, 0.88
Head AIS score	0.52	0.49, 0.55
Mechanism**	4.03	3.37, 4.83
Transfer status***	0.80	0.69, 0.92

* Year of admission, age, and body region AIS scores are treated as linear variables in the logistic regression model.
** Blunt mechanism = 1, penetrating mechanism = 0.
*** Transfer from another institution = 1, direct admission from scene = 0.

On further detailed analysis, the reduction in the mortality rate was more pronounced in direct admissions with severe injuries. The crude case-fatality rate declined in those with an ISS ≥16 admitted directly from the scene (20.0% in 1986 to 17.6% in 1995, p = 0.04) and in those transferred from outside institutions (16.4% in 1986 to 14.4% in 1995, p = 0.08). Adjusting for age, mechanism, and severity of injury, the reductions in mortality rate were more marked and statistically significant in both these groups. Of 7681 patients with an ISS ≥16, 86% suffered blunt trauma and 14% were victims of penetrating trauma. The crude mortality rate in blunt-trauma victims declined from 17.4% to 14.7% (p = 0.002). In penetrating trauma victims, there was more marked fluctuation in the yearly crude mortality rates, ranging from a high of 39% in 1989 to a low of 24% in 1994 (p = 0.3). However, after adjusting for the effects of injury severity, age, and transfer status, the reduction in mortality rate over time in severely injured patients with penetrating trauma decreased at a similar rate to the reduction in mortality rate in severely injured blunt-trauma patients.

There were no specific injuries associated with a clear reduction in mortality rate over time. After controlling for regional AIS scores, ISS, age, and transfer status, the mortality rate associated with pelvic fractures, femur fractures, or closed head injuries did not change over time. Similarly, mortality rate for patients with spleen or liver injuries did not change.

DISCUSSION

Over the past two to three decades, changes in the care of the injured patient have occurred. At the institution and regional level, an organized approach to care has been shown to result in improved survival. Mullins et al[5] demonstrated a reduction in mortality rate in patients with injury severity scores ≥16 after establishment of a regional trauma system. Other investigators have demonstrated that trauma centers and organized systems minimize preventable deaths and population-based mortality rates after injury.[1,6,13–15] Our study suggests that even in the presence of a systematic approach to trauma care, improvements in survival outcome will still be achieved over time.

However, there are a number of barriers that appear to have limited more widespread advancement of trauma care. Goldfarb et al[12] suggest that trauma center care is more costly that care in other centers, and this cost differential remains after controlling for the severity of injury. Trauma care is costly, and our study has demonstrated an increase in the hospital costs of trauma care over time. However, the 17% increase in costs over 10 years is fairly modest compared with the overall increase in total health care costs. However, because this is the first study to examine cost trends in trauma patients, there are few standards with which to compare our figures. We can conclude that the increase in survival was achieved at a modest cost increase; however, we must be careful not to make inferences beyond the level I trauma center. The results of our study do not allow us to make conclusions regarding the costs of care in an inclusive trauma system. Moreover, we have no standard against which to compare changes in costs over time. Ideally, conclusions concerning cost control at a busy trauma center will require comparisons with other centers providing trauma care, including designated level II and level III centers and undesignated hospitals.

Previous work has suggested a minimum case volume to ensure adequate outcomes, also supporting the limitation of center designation.[16,17] Although controversial, these studies have been used to support limitations on the number of centers receiving trauma center designation. The American College of Surgeons supports limiting trauma center designation to ensure a level of experience necessary to maintain expertise.[18] It is presumed that greater experience and expertise lead to better outcomes, but this has not been conclusively shown for complex trauma patients. Limiting trauma center designation places a burden on available resources at centers accepting this role. Thus, a recommendation to restrict center designation requires significant commitment from a region to support the designated centers, and must rest on sound data. Our study provides supporting evidence for restricting the number of trauma centers so designated by demonstrating a continued improvement in survival over time as case volumes and cumulative experience have increased. The nature of this problem is such that data will never be available from a randomized clinical trial, and we must rely on evidence from nonexperimental studies. The association of a reduction in mortality rate with time should not infer causation; however, our evaluation supports such a conclusion.

Trauma center care is expected to be of greatest benefit to severely and multiply injured patients who are at greatest risk of dying from their injuries. This study identified the most marked reduction in mortality rate in patients with an ISS ≥16, suggesting that increased experience with more complex injuries contributes to improved survival. Changes in the practice of trauma care, such as the increased use of CT and angiography, have allowed for nonoperative management of liver and spleen injuries (abdominal CT) and have provided potentially more effective methods to control life-threatening hemorrhage (pelvic angiography).[19,20] However, we are unable to attribute a reduction in mortality rate to the application of these technologic advances, nor were we able to identify specific injuries in which the survival rate increased over time.

A notable peculiarity at the study center regarding the infrequent use of abdominal CT scanning warrants discussion. The increasing use of abdominal CT scanning in the first half of the study period was followed by a decrease from 1993 forward. This reduction was primarily related to an increased reliance on diagnostic peritoneal lavage to exclude intraperitoneal injuries in hemodynamically stable patients.[21] This approach did not appear to reduce directly the mortality rate specifically in patients with blunt abdominal injuries, but facilitated the nonoperative management of hepatic and splenic injuries without increasing costs in this group of patients.

Are we justified in inferring that experience increased with time and that this increase in experience contributed to improved survival? This is the major potential criticism of this study. The most difficult conclusion to reach is that the improvement in survival is directly related to cumulative experience. It is difficult to sort out the effects of various factors on survival improvement. Increasing attention toward trauma management at regional and statewide levels may have resulted in improved prehospital care and faster triage to definitive care. We are unable to evaluate the impact of such potential changes from our data. Further investigation will be required to determine if specific changes in trauma care, some of which we have evaluated, contribute to improved survival.

Increasing cumulative experience may be partly responsible for the survival benefit of trauma center designation and system implementation. Although it impossible to remove the effect of this confounding factor, in our study we attempted to evaluate the effects of time and experience in greater detail. In comparing survival outcome in level I trauma centers over an 8-year period during which time an organized trauma system was established, Mullins et al[5] demonstrated a reduced risk of death (OR = 0.65) over the entire period. Limiting analysis to 1986 and 1995, the present study demonstrated an OR for death of 0.70 (95% CI 0.52, 0.91). Our study supports the contention that experience improves survival outcome in severely injured patients. This suggests that restricting the trauma center designation based on population-based needs within a region is appropriate to maximize the experience at individual trauma centers. We believe that trauma system development must aim to achieve optimal survival outcomes, not "normative" or average outcomes based on statistical conformation to a presumed expected survival rate. Thus, attempts to determine minimal case volumes to achieve acceptable survival are inappropriate.

Potential biases must be considered when interpreting our findings. Over a 10-year period, the methods of data management may change, introducing bias if the change were somehow systematic. We are unaware of any changes in the data collection process and criteria in this study, aside from that related to the collection of information on radiologic investigations. In 1986, radiologic investigations were not recorded directly from the chart, but rather from the hospital separation summary, which may have led to underreporting of these investigations. For this reason, 1986 was excluded from the analysis of radiologic investigations. By excluding ED deaths, bias may have been introduced into our analysis of overall mortality rate if the proportion of ED deaths changed during the 10 years. For instance, a reduction in hospital fatalities could simply be caused by a shift to other phases of care, such as the ED. In this study, the lowest rate of ED deaths occurred in the later years of the study, indicating that if there were a shift, it was from the ED to the later phases of care.

CONCLUSIONS

Increasing experience over time is associated with improved survival outcomes in severely injured trauma patients. This improved survival can be achieved at modest increases in hospital costs. Our finding of a reduction in mortality rate is of considerable importance as trauma care advances into the next century, and we believe that the trauma center must remain central to trauma system development. The experience gained at a high-volume center should be protected by limiting the number of trauma centers, directing the transport of major trauma victims to these centers, and providing the resources to enable these centers to deal effectively with a high volume of trauma patients.

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