Impact on Patient Outcomes after Closure of an Adjacent Trauma Center

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In 2005, a major Level I trauma center closed in Los Angeles County, leading to media speculation that the sudden expansion of our catchment area would adversely affect outcome. We sought to determine whether the closure led to longer transport times and increased trauma morbidity and mortality at our Level I trauma center. Annual patient volume, paramedic transport times, injury severity score (ISS), mechanism of injury, complication rate, and mortality were retrospectively compared between two time periods, Period 1 (1997–2005, before closure) and Period 2 (March 1, 2005 to March 1, 2006, after closure), using multivariable logistic regression models. Median monthly patient volume rose from 123 patients to 190 patients in Period 2 (P < 0.01). Median transport time increased from 12 to 13 minutes (P = 0.004) and median ISS increased from four to five (P < 0.01) in Period 2. The proportion of patients with ISS > 15 increased from 17 to 24 percent as well (P < 0.01). After accounting injury severity, the adjusted mortality rate decreased in Period 2 (odds ratio 0.69, P = 0.03) and the adjusted complication rate was unchanged (odds ratio 1.16, P = 0.2). In conclusion, the closure of a Level I trauma center resulted in a significant increase in trauma patient volume and injury severity, as well as a slight increase in paramedic transport times. However, the adjusted complication rate was unchanged, and the adjusted mortality rate actually improved.

Methods

The study was approved by the Human Subjects Committee of the Los Angeles Biomedical Research Institute at Harbor-UCLA Medical Center. Patient records from January 1, 1997 to March 1, 2006 contained within the Trauma and Emergency Medicine Information System, a prospectively collected database, were retrospectively reviewed. Because one of the objectives of the study was to compare transport times, only trauma patients transported to our institution by ground ambulance were included in the analysis. Patients were divided into two time periods: Period 1 (before the closure of the adjacent trauma center) from January 1, 1997 to February 28, 2005 and Period 2 (after the closure of the adjacent trauma center), March 1, 2005 to March 1, 2006.

Data collected included age, mechanism of injury, ISS, mechanism of injury, complication rate, and mortality at our Level I trauma center. The study was approved by the Human Subjects Committee of the Los Angeles Biomedical Research Institute at Harbor-UCLA Medical Center. Patient records from January 1, 1997 to March 1, 2006 contained within the Trauma and Emergency Medicine Information System, a prospectively collected database, were retrospectively reviewed. Because one of the objectives of the study was to compare transport times, only trauma patients transported to our institution by ground ambulance were included in the analysis. Patients were divided into two time periods: Period 1 (before the closure of the adjacent trauma center) from January 1, 1997 to February 28, 2005 and Period 2 (after the closure of the adjacent trauma center), March 1, 2005 to March 1, 2006.

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All patient data were transferred from the Trauma and Emergency Medicine Information System registry into an Excel database (Microsoft Excel, Microsoft Corporation, Redmond, WA) and translated into a native Statistical Analysis Software (SAS) format using DBMS/Copy® (Dataflux Corporation, Cary, NC). Numerical variables were compared using the nonparametric Wilcoxon rank sum test and are reported as medians with interquartile ranges (IQRs). Categorical or nominal variables were compared using the \( \chi^2 \) test or Fisher's exact test, as appropriate. To determine the separate effects of the adjacent trauma center closure and overlying secular trends on the volume of trauma patients at our institution, we performed multivariable linear regression with time and adjacent trauma center status as the two predictor variables.

A trauma and injury severity score (TRISS) was calculated using the ISS, revised trauma score, and age index. This score was adjusted for mechanism of injury (blunt vs penetrating) as well as for age. Multivariable logistic regression models were used to determine independent predictors of survival and the occurrence of complications with adjustment by known confounders. Confounders were included by creating a “TRISS-adjusted” model that included the logit of the TRISS-calculated probability of survival as an independent predictor. In this way, we could test for influence on mortality and complications independent from, and in addition to, the factors incorporated in the TRISS model. A significance level less than 0.05 was deemed statistically significant and no adjustment was made for multiple comparisons. All statistical comparisons were performed with the SAS statistical software package version 8.2 (SAS Institute, Cary, NC).

**Results**

**Descriptive Data for Overall Study Period**

Over the 10-year period, 14,996 patients were brought to the trauma center via premedic ground transport. Annual patient volume from years 1997 to 2005 increased as follows: 1,265, 1,260, 1,305, 1,476, 1,493, 1,605, 1,696, 1,948, and 2,240 patients, respectively (\( P < 0.0001 \)). The median age was 30 years (IQR 19–47), and the median ISS was five (IQR 1–10). The median transport time was 12 minutes (IQR 9–17). Mechanism of injury was blunt in 83 per cent and penetrating in 17 per cent of patients. The most common mechanism of injury was motor vehicle collision (31%), followed by a fall greater than 15 feet (21%). The overall complication rate was 2.9 per cent, with pneumonia (46% of complications) being the most common. Overall, 852 patients died (mortality rate of 5.7%), of which 111 (13% of all deaths) were dead upon arrival to the ED. The median hospital length of stay was 2 days. Patient disposition from the ED was as follows: 34 per cent were discharged home, 28 per cent were admitted to the ward, 25 per cent were admitted to the ICU or step down unit, 12 per cent went directly to the operating room, and 1 per cent were taken directly to Interventional Radiology.

**Comparison of Time Periods**

Trauma patient characteristics

When comparing the two time periods, the median monthly volume increased from 123 (IQR 106–142) to 190 (IQR 178–207) (\( P < 0.0001 \)) (Table 1). Figure 1 demonstrates that even after accounting for the effect of secular changes on monthly trauma volume, there was an additional step increase in volume associated with closure of an adjacent trauma center of 31 (95% confidence interval 18.5–43.7) patients/month. The median age decreased from 31 (IQR 19–47) to 29 years (IQR 19–46) (\( P = 0.02 \)). Median transport time increased from 12 (IQR 8–17) to 13 minutes (IQR 9–17) (\( P = 0.004 \)). The median ISS increased from four (IQR 1–10) to five (IQR 4–14) (\( P < 0.0001 \)). The proportion of patients with an ISS > 15 increased from 17 per cent in Period 1 to 24 per cent in Period 2 (\( P < 0.0001 \)). The bottom panel of Figure 1 demonstrates that the increase in median ISS actually preceded the

<table>
<thead>
<tr>
<th>Variable</th>
<th>Period 1 (12,639)</th>
<th>Period 2 (2357)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly patient volume</td>
<td>123 (IQR 106–142)</td>
<td>190 (IQR 178–207)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Age (years)</td>
<td>31 (IQR 19–47)</td>
<td>29 (IQR 19–46)</td>
<td>0.02</td>
</tr>
<tr>
<td>Transport time (minutes)</td>
<td>12 (IQR 8–17)</td>
<td>13 (IQR 9–17)</td>
<td>0.004</td>
</tr>
<tr>
<td>ISS</td>
<td>4 (IQR 1–10)</td>
<td>5 (IQR 4–14)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>ISS &gt; 15</td>
<td>17% (2170)</td>
<td>24% (565)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Revised trauma score</td>
<td>7.84 (IQR 7.84–7.84)</td>
<td>8 (IQR 7.84–8)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>TRISS based POS</td>
<td>99.44% (IQR 99.3–99.67)</td>
<td>99.42% (IQR 97.93–99.63)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Penetrating trauma rate</td>
<td>16% (1974)</td>
<td>24% (543)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Complication rate</td>
<td>2.8% (340)</td>
<td>3.9% (91)</td>
<td>0.003</td>
</tr>
<tr>
<td>Mortality rate</td>
<td>5.4% (662)</td>
<td>7.3% (167)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length of stay (days)</td>
<td>2 (IQR 1–4)</td>
<td>2 (IQR 1–4)</td>
<td>1</td>
</tr>
</tbody>
</table>

POS, probability of survival.
study year 8 in the upper panel of the graph denotes the time at which the adjacent trauma center closed. The bottom panel plots median ISS with error bars showing IQRs, and demonstrates an increase in median ISS that preceded the closure by more than a year (see text).

 closure of the adjacent trauma center by more than a year. The median TRISS-based probability of survival decreased from 99.44 per cent (IQR 98.3–99.67%) to 99.42 per cent (IQR 97.93–99.63%) (P = 0.0002).

Mechanism of injury

There was significant increase in the percentage of penetrating trauma from Period 1 to Period 2 (16 to 24%, P < 0.0001), with an increase in the percentage of gunshot wound (11 to 18%, P < 0.0001) and burns (0.45 to 1.1%, P = 0.002). There was a decrease in the number of motor vehicle collisions (33 to 26%, P < 0.0001) and falls (22 to 19%, P = 0.003) in the latter time period.

Patient disposition

There was a statistically significant change in the pattern of patient disposition from the ED with decreases in ICU admission (14.3 to 13.6%), discharge to a step-down unit (10 to 8%), and use of the ward (29 to 24%), and increases in use of the odds ratio (12 to 13%) and in discharge directly home (33 to 39%) (P < 0.0001). The median length of stay was unchanged at 2 days (IQR 1–4).

Patient outcome

The mortality rate increased from 5.4 per cent to 7.3 per cent in Period 2 (P < 0.0001). There was an increase in the number of patients presenting to the ED in traumatic full arrest from 0.6 to 1.5 per cent (P < 0.0001). The raw, unadjusted odds ratio for mortality was 1.4 for Period 2 relative to Period 1 (CI 1.2–1.7, P = 0.0002). After adjusting for the TRISS model risk of death, the odds ratio for mortality in Period 2 relative to Period 1 was 0.69 (CI 0.49–0.97, P = 0.03). In Period 2, the complication rate increased from 2.8 to 3.9 per cent (P = 0.003) [unadjusted odds ratio of 1.44 (95% CI 1.14–1.83), P = 0.002]. With respect to the specific complications incurred, there were no differences with respect to external pancreatic fistula, jaundice/hepatic failure, empyema, pulmonary embolism, renal failure, intra-abdominal abscess, and adult respiratory distress syndrome between the two time periods. There were increases in the incidences of pneumonia (1.2 to 2.2%, P < 0.0001), septicemia (0.18 to 0.43%, P = 0.03), surgical wound infection (0.36% vs 0.65%, P = 0.05), and surgical wound dehiscence (0.03 to 0.17%, P = 0.03) in the second time period.

TRISS-based mortality predictions could be calculated for 10,843 of 12,638 (86%) and for 2,261 of 2,357 patients (96%) in Periods 1 and 2, respectively. In the trauma center preclosure period, the predicted number of deaths was 535; however, there were 505 observed mortalities. In Period 2, the predicted number of deaths was 190, whereas the actual number of deaths was 165. Although the actual number of deaths were less than predicted for both periods, these differences were not statistically significant.

Discussion

In recent years, concern has mounted that the number of injured patients nationwide has overwhelmed our current healthcare system. These fears are particularly acute in Los Angeles County because there has been a significant population influx and several emergency departments and trauma centers have closed. At our institution, the closure of an adjacent trauma center created worries that rising patient volume would result in a prolongation of transport times, and ultimately, an increase in patient morbidity and mortality. The present study demonstrated more than a
77 per cent rise in trauma volume, and an increase in injury severity. Somewhat surprisingly, however, paramedic transport times only slightly increased. Despite higher ISS scores, on multivariable analysis the adjusted probability of death decreased in the post-trauma center closure period and the adjusted complication rate was unchanged. Hiatt et al. demonstrated that the closure of an adjacent trauma center resulted in significant increases in patient volume and penetrating injury. The authors noted an increased mortality rate from 4.6 to 6.3 per cent, though this difference was not statistically significant. The increase in transport time observed in the present study, although statistically significant, represented only an additional 30 seconds, and did not seem to be clinically significant. The improved outcome seen in the risk-adjusted analysis in the present study may be the result of increased experience. O'Keefe et al. demonstrated that over a 10-year period at a Level I trauma center, the case-fatality rate declined in patients with severe injuries, attributing their findings to increased experience.

Despite the increase in patient volume and injury severity, the overall complication rates were unchanged. Infections were the primary source of morbidity. Prior studies have suggested that hospitalized trauma patients have an increased risk of nosocomial infections secondary to a state of relative immunosuppression. Papia et al. demonstrated that out of 563 trauma patients, 37 per cent of patients developed at least one infection. In trauma victims who survived greater than 3 to 5 days, infection was second to severe head injury as the leading cause of death. Papia et al. reported that hospital associated infections in trauma patients were not associated with increased mortality rates. Although infections were the main source of morbidity in the present study, there was a statistically significant decline in DIC, which may reflect the importance of “damage control” surgery in preventing the onset of the lethal triad of coagulopathy, acidosis, and hypothermia.

There are several explanations for the observed outcomes in the study. The findings may be a reflection of our increased patient volume, which expectedly expanded our experience. With the advent of the 80-hour workweek and the termination of Martin Luther King's (MLK) surgery program, several modifications were made within the trauma program. This included the addition of a dedicated nurse practitioner to the Trauma Service as well as the incorporation of four MLK surgery residents within our department at various levels. Before MLK's closure, an additional fellowship-trained trauma attending came on board. Furthermore, the resident trauma complement was also reorganized into three smaller teams in an effort to more evenly distribute patient care. Such modifications to our system may serve as a useful model for other institutions experiencing abrupt increases in trauma patient volume. Recent advancements in critical care including ventilatory management, resuscitation, antibiotic coverage, and organ support modalities may also partially explain the observed outcomes. Previous studies have favored limited resuscitation in patients with vascular injuries and damage control techniques, practices that we have also adopted with our trauma patients. Finally, our results may also be a reflection of the mature trauma system established within Los Angeles County. Such trauma systems have been shown to substantially reduce injury-related morbidity and mortality. Given the size and maturity of the Los Angeles County trauma system, the increase in patient volume after MLK's closure was distributed among several remaining trauma centers. It is evident, as supported by the current study, that the remaining trauma centers were able to absorb this increase in patient volume without affecting outcome.

In conclusion, despite the closure of an adjacent Level I trauma center, our institution was able to successfully absorb the increased volume, injury severity, and percentage of penetrating injuries without affecting the adjusted mortality or the overall complication rates. In fact, after adjusting for TRISS, mortality in the second period was actually improved, a finding that is likely the result of increased experience. Transport times only increased by 1 minute, an increase that is apparently not clinically significant. Our findings attest to the importance of trauma center designation as well as to the ability of a mature Level I trauma center to adjust to sudden increases in volume. Further studies are required to determine whether a volume threshold exists such that any increase above that value will adversely affect the quality of care.

REFERENCES
