Does Hospital Surgical Volume Affect In-Hospital Outcomes in Surgically Treated Pelvic and Acetabular Fractures?

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Abstract
A retrospective evaluation was done to determine the relationship between hospital volume and in-hospital mortality, complications, and length of stay in patients with operatively treated fractures of the pelvis or acetabulum. Patients were divided into three groups based on hospital volume. High volume centers had higher percentages of patients with one or more comorbidities, but who were less severely injured. Mortality rates were highest in small volume centers. Moderate volume centers had the lowest odds of death. Complication rates were similar between small and high volume hospitals. Length of stay was shortest in high volume centers. In-hospital outcomes associated with surgical fixation of the pelvis, acetabulum, or both were not uniformly associated with hospital volume.

Fractures of the pelvis and acetabulum remain some of the most challenging injuries facing the orthopaedic surgeon. Operative treatment of these injuries may result in substantial morbidity and mortality. Pelvic fractures are typically associated with high energy trauma and are often accompanied by severe intra-pelvic and intra-abdominal injuries that require multidisciplinary care. Fracture reduction and internal fixation is often technically demanding, and the reduction quality has been demonstrated to predict outcome for acetabular fractures.

Numerous studies have attempted to quantify the relationship between surgical volume and outcome for orthopaedic procedures. A direct relationship between volume and improved clinical outcome has been demonstrated for elective procedures, such as total hip, knee, and shoulder arthroplasty. In contrast, few studies have examined the relationship between case volume and orthopaedic trauma. Furthermore, these studies were limited to hip fractures. In general, hip fractures are low energy injuries treated by generalists in orthopaedics. In contrast, pelvic and acetabular fractures are high energy injuries and are often managed by fellowship-trained traumatologists.

With the technical skill required to operatively fix pelvic and acetabular fractures, and the frequent need for multidisciplinary care, it has been generally accepted that specialized centers may best treat these injuries. However, to date no study has examined the relationship between hospital volume and outcome for these fracture types. It was hypothesized that hospitals with increased surgical volume would have lower rates of morbidity and mortality, and subsequent decreased lengths of patient hospitalization when operating on patients with pelvic and acetabular fractures.

Materials and Methods
Data Source
The data in this study were obtained from the National Trauma Data Bank (NTDB), Version 4.3, which includes over 1.21 million trauma cases from 377 institutions gathered from 1988 through 2004. The databank is managed through the American College of Surgeons (ACS) and gathers data from 55% of all level I trauma centers, 35% of level II trauma centers, and many level III trauma centers throughout the United States. Data entry is voluntary at participating hospitals and, therefore, may not reflect the actual number of trauma cases.
of trauma patients seen at an institution. Further, the NTDB provides no weighting information that would allow the user to estimate national incidence rates.

**Sample Selection**

Adult patients, defined as 18 years of age or older, who sustained a pelvic or acetabular fracture were identified from the NTDB using the ICD-9 code of 808 for pelvic or acetabular fractures. The procedural code of 79.39 was used to indicate open reduction with internal fixation (ORIF). Patients were excluded from the study if the database did not include year of admission or did not have a valid ISS (injury severity score), length of stay, or mortality status.

Each record in the dataset represents a single patient’s hospitalization for the trauma. However, the dataset does not include unique patient or surgeon identifiers; and, therefore, readmissions cannot be tracked.

**Outcome Measures**

The three primary outcomes were: 1. in-hospital mortality, 2. complications, and 3. length of stay. In-hospital mortality was based on discharge status (alive or dead). Selected complications were determined by searching the concurrent ICD-9 codes associated with the hospitalization for the injury and identifying the most common as well as the most serious complications. These complications were, therefore, by definition in-hospital events. Length of stay was determined from the date of admission to discharge (or death).

**Main Effect**

The primary predictor variable was hospital volume. The number of open reduction and internal fixation cases for pelvic and acetabular surgery per month allowed stratification of the hospitals into three different groups (small, medium, and large volume hospitals). Small volume hospitals were defined as averaging less than two procedures per month (under 24 per year). Moderate volume hospitals performed two to five operations per month (24 to 59 per year). Large volume centers had five or more operations per month (under 24 per year). Moderate volume hospitals performed two to five operations per month (24 to 59 per year). Large volume centers had five or more operations per month (equal to or greater than 60 per year). These volume cut-off points were selected to both obtain approximately similar percentages in each of the three groups and to have clinically relevant delineations.

**Covariates**

NTDB includes information on patient age, sex, race, and ISS. The ISS is an anatomical scoring system used to evaluate patients with multiple injuries. The body is divided into nine regions (head, face, neck, thorax, abdomen, spine, upper extremities, lower extremities, and unspecified). Each region is assigned an individual score from 0 to 6 (from no injury to not survivable). The top three most severely injured body regions are squared and added together to determine total ISS score (0 to 75 points possible for a living patient).

In addition, the Deyo-Charlson Comorbidity Index (DCCI) was derived from ICD-9-CM diagnostic codes and contains 19 categories of comorbidity, each with associated weight based on an adjusted risk of one-year mortality. The overall comorbidity score reflects the cumulative increased likelihood of one-year mortality; the higher the score, the more severe the burden of comorbidity.

Additional covariates accounted for in the analysis included: hospital type (teaching vs. non-teaching and public vs. private), geographic region of hospital location, hospital discharge disposition (death, home, nursing facility, rehabilitation center, hospital transfer, and other), and year of admission.

**Analysis**

Logistic regression techniques were used to evaluate the relationship of hospital volume with mortality, length of stay, and complications. Since mortality is inherently a dichotomous variable, the logistic regression approach was clear. Anticipated low rates for individual complications suggested that the most powerful means for evaluating complications would be to aggregate complications for a patient and then classify each patient as not having or having complications (0 vs. 1+). For length of stay, the distribution of scores is typically not normally distributed. Instead, the distribution is skewed right, with a large number of counts at the low end of the scale (e.g., 2 to 4 days), but with still appreciable counts of much larger numbers (often more than 40 days). Thus, the length of stay outcome was also dichotomized. For this cohort, the cut score for length of stay was planned to be set at the median.

Preliminary logistic regressions evaluated the relationship of each outcome with hospital volume only to establish baseline or unadjusted odds ratios for small and moderate volume hospitals referenced to high volume hospitals. Subsequent analyses included patient covariates, such as patient age, gender, comorbidity status, and so forth, to estimate adjusted odds ratios.

**Results**

**Cohort Summary**

A preliminary analysis of the 15 years of data available in the NTDB, Version 4.3, data bank revealed low counts for the cohort of interest in years prior to 1997 and in 2004. The number of hospitals participating in the NTDB in 1996 and earlier was small and all were almost exclusively low-volume centers. Therefore, only the years 1997 through 2003 were included for subsequent analyses.

Figure 1 summarizes the results of the patient inclusion and exclusion criteria that established the cohort for analysis. Of the 9386 patients in the data base who met study inclusion criteria, 4% (386/9386) were lost due to missing outcomes, and an additional 3% (261/9386) were lost due to limiting the data from 1997 to 2003. These 8736 patients represent 93% of the identified cohort of adult patients treated with open reduction and internal fixation (ORIF) and an additional 3% (261/9386) were lost due to limiting the data from 1997 to 2003. These 8736 patients represent 93% of the identified cohort of adult patients treated with open reduction and internal fixation (ORIF).
reduction and internal fixation for their pelvic or acetabular fracture.

Of the 8736 study patients, roughly, one-third was in each of the three volume groups. However, as illustrated in Figure 2, the number of hospitals within each group was quite different: 189 hospitals were in the small volume group, 27 in the medium volume, and 7 in the high volume group. On average, a small volume center performed 11.6 cases of fixation for acetabular and pelvic fractures per year, medium volume centers performed 39.1 cases per year, and high volume centers performed 88.8 cases per year. Hospitals consistently fell within the same volume status in successive years for the 7 years the NTDB was evaluated.

Tables 1 and 2 summarize cohort demographics overall that are broken down by hospital volume. Patient age was not significantly different across the low, medium, and high volume hospitals (p < .241). Overall, patients were relatively young, with an average age of 40.4 years, and predominantly Caucasian. Although ISS was statistically significantly different across hospital volume categories (p < .0001), follow-up tests indicated that small and moderate volume hospitals were not significantly different from each other (16.4 vs. 16.2, p < .34). In addition, the 1 point difference in ISS scores between the high compared to the small and moderate volume centers, although statistically significant, was not considered clinically relevant.

High volume centers were more often teaching or private hospitals and treated higher rates of Caucasian patients. As might be expected with a young population, comorbidities were generally low. Additionally, patients in high volume hospitals were more likely to have one or more comorbidities. Medium volume centers treated a higher proportion of black patients and were intermediate for ISS and DCCI scores. Small volume centers were least likely to be a teaching facility, and patients were least likely to have any comorbidity. In addition, patients treated at small volume hospitals were least likely to be sent home (46% vs. 54%, L to H) and most likely to be transferred to another hospital (6.1% vs. 1.2%, L to H).

### Primary Outcomes

#### Mortality

In-hospital mortality was 1.5% (133/8736). As summarized in Table 3, unadjusted in-hospital mortality showed patients at small volume centers to be 2.76 times (OR, 2.76; 95% CI, 1.80 to 4.24) and 2.62 times (OR, 2.62; 95% CI, 1.65 to 4.15) more likely to die than patients at medium and high volume centers, respectively. There was no difference in unadjusted mortality rates between medium and high volume hospitals.
(OR, 0.95; 95% CI, 0.54 to 1.63). When adjusting for patient and hospital factors, patients treated at a small volume center were still more likely to die than patients treated at a medium volume center (OR, 1.74; 95% CI, 1.04 to 2.91). Contrary to unadjusted rates, there was no difference in mortality between small and high volume centers (OR, 0.68; 95%
Furthermore, after adjustment, a patient treated at a medium volume center was 62% less likely to die than those treated at high volume institutions (OR, 0.38; 95% CI, 0.20 to 0.74).

Complications
On average, specific complications were rare. On the other hand, when considering overall medical and surgical complications at the patient level, where no complications were coded 0 and any complication was coded as 1, 33.7% of patients had at least one complication coded. Only five of 24 complications occurred more than 2% of the time [bladder injury (5.38%), postoperative anemia (4.13%), post-traumatic pulmonary insufficiency (2.72%), sciatic nerve injury (2.2%), and ileus (2.08%)] (Table 4). Over half of the complications (11/24) showed no difference between groups. For the 11 complications that did show significant p values, the smaller volume centers had the lowest complication rates and the large volume centers had the highest complication rates 82% of the time.

As summarized in Table 5, unadjusted odds ratios indicated that small volume centers were protective of complications by 19%, compared to medium and high volume centers (OR, 0.81; 95% CI, 0.72 to 0.90, and OR, 0.81; 95% CI, 0.72 to 0.91). Risk of complications were not significantly different in moderate compared to high volume centers (OR 1.00; 95% CI, 0.89 to 1.12). When adjusting for patient and hospital factors, no significant differences in complication rates were observed between the low, moderate, and high volume centers.

Length of Stay
Length of stay was shortest for high volume centers, with mean lengths of stay of 15.3, 14.5, and 13.0 for low, mod-
erate, and high volume hospitals, respectively. The overall median length of stay was 11 days. Odds ratios for length of stay dichotomized for periods of 10 days or less and more than 10 days were evaluated to eliminate outlier effects.

As summarized in Table 6, there was no significant difference for prolonged lengths of stay between small and medium volume centers for both unadjusted and adjusted odds ratios (1.07 and 1.06, respectively). However, the adjusted odds of staying greater than 10 days at small and medium centers, as compared to a high volume center, were 68% (OR 1.68; 95% CI, 1.45 to 1.93) and 58% (OR 1.58; 95% CI, 1.39 to 1.80) greater, respectively.

**Discussion**

Previous studies have generally supported the conclusion that higher volume centers provide care that results in lower morbidity and shorter lengths of stay following elective arthroplasty and low-energy hip fracture orthopaedic procedures. To the best of our knowledge, this is the first study to investigate the relationship between hospital surgical volume and outcome for patients being treated for high energy injuries that are felt to require interdisciplinary team care involving specialty trained orthopaedic surgeons.

Seven years of data from trauma centers across the country were evaluated to address the question of whether or not hospital surgical volume affects the mortality, in-hospital complication rates, and length of stay for patients undergoing pelvic and acetabular surgery. The similarities in patient ages and injury severity across the three hospital volume categories were surprising. It was expected that high volume hospitals would generally be level I trauma centers and, therefore, due to hospital transfer, would generally treat older, sicker, and more severely injured patients. However, in our sample, the hospital trauma level was missing for more than 40% of the patients. Therefore, we were unable to determine whether or not the lack of differences between small, medium, and high volume trauma centers relative to patient age and injury severity was due to an error in our assumption that high volume hospitals were likely to be level I trauma centers. The general low comorbidity levels across all groups may also be explained by the general similarity in patient ages across the small, medium, and high volume centers. These results indicated that small volume centers were treating the highest percentage and high volume centers were treating the lowest percentage of patients categorized as having severe or very severe injuries based on ISS. Again, this result was counter-intuitive, since the common wisdom is that patients with higher injury severity tend to be transferred to level 1 trauma centers. As a consequence, level 1 trauma centers would be more likely to be high volume centers. The reasons for the general low incidence of hospital transfer observed in these data remain unclear.

Across all groups, complications and mortality rates were low and compare similarly with previously reported death and morbidity levels. Overall, small volume centers had the highest mortality rate at 2.53%, more than double the mortality rates at the medium (0.93%) and high (0.98%) centers. Adjusting for patient’s personal and health demographics, injury severity, and hospital differences significantly altered the interpretation of mortality rates relative to hospital volume. Unexpectedly, moderate volume centers were significantly protective of in-hospital mortality, compared to high volume centers. One
possible explanation for this lower mortality rate is that medium volume hospitals may treat the patient and then transfer them soon after, in which case, mortality may occur but not at their facility. The pattern of discharge status is supportive of this view, with medium volume hospitals transferring 4.93% of their cases, compared to 1.23% in high volume hospitals.

Small volume centers had significantly fewer numbers of complications than medium and high volume centers, with no reliable differences in complications between medium and high volume centers. After adjusting for potentially confounding factors, small volume centers still demonstrated lower complication rates compared to moderate volume centers.

There are several explanations for why small volume centers may have a lower complication rate. Patient cases that are inherently more complex or with features thought to be prone to complications may be transferred to centers more accustomed to treating these patients. The highest rate of inter-hospital transfers in the lower volume centers lends support to this conclusion. Since this database is composed only of ICD-9 billing codes or procedures performed during the hospitalization, the downstream set of complications and morbidity for the subset of sick transferred patients cannot be ascertained. This explanation may also provide insight as to the lower mortality rates in medium as compared to both small and high volume facilities.

An additional explanation for the disparity in complication rates may be that well established centers of care may have screening systems in place to detect more common complications. For example, all postoperative pelvic and acetabular patients may undergo routine urinary analysis to evaluate for urinary tract infections (UTIs) or screening duplex studies to detect deep vein thrombosis (DVT). The fact that significantly higher complications are found in medical complications (anemia, DVT, UTI, and decubitus ulcers) support this conclusion. These screening programs may elevate complication rates in higher volume centers, but actually improve long-term patient outcomes.

Previous orthopaedic studies have demonstrated an inverse relationship between hospital volume and negative outcomes. However, these reports differ from our research, as they examined elective surgery (arthroplasty) or low energy trauma commonly treated by generalists in orthopaedics (hip fractures), while our focus was high energy trauma typically managed by fellowship-trained traumatologists. It is hypothesized that complex trauma cases may be more likely to be initially managed at the presenting institution and then transferred to specialized centers for more definitive care if the case complexity or patient comorbidities warrants transfer. This transfer of care is less likely to occur in elective and routine operative conditions. This discrepancy may, in-part, explain the difference between the results in this paper and previous works.

The importance of these results impacts more than patient outcomes. The effect of hospital volume on outcome has socioeconomic impact on patient care. Length of stay is an important determinant of cost. With increased emphasis on cost containment and decreasing reimbursements, strategies to decrease costs while maintaining care are valuable. The results of this study preliminarily indicate higher volume centers have reduced length of stay. This result may translate to cost containment strategies for caring for patients undergoing surgery for pelvic and acetabular fractures.

One major limitation of this study is the inability to evaluate the complexity of the fracture. Thus, it is possible that small volume hospitals may have treated simpler fracture types, transferring more complex fractures to another hospital prior to surgery and, therefore, they would not have been included in the cohort. This would explain lower complication rates in small volume centers, but also would suggest the disturbing possibility that small volume centers had higher mortality rates despite treating less complex cases. It should be emphasized, however, that the limitation is that the lack of available data does not allow the ability to confirm or refute this hypothesis.

A second major limitation of this study is the inability to evaluate post-hospitalization patient outcomes. Previous work on outcomes following acetabular fractures has emphasized the importance of fracture reduction to prevent long-term complications, including arthritis and the need for additional procedures. Patients’ ability to return to pre-injury function, need for re-operation, satisfaction with care, and the long-term outcome from the complication rates cannot be evaluated.

Another limitation is the translation of hospital surgical volume to surgeon surgical volume. The NTDB does not allow stratification of surgeries based on surgeon volume. It is therefore possible that a small volume hospital will have a high volume pelvic and acetabular surgeon performing all of these trauma surgeries. To the contrary, a high volume center may have multiple surgeons performing the operations. Therefore, each of the surgeons may be low volume pelvic and acetabular surgeons. As a result, from this database, we were unable to conclude the effect of surgeon volume on outcome for patients with pelvic and acetabular open reduction and internal fixation.

Conclusion

For the complex nonelective orthopaedic procedure involving surgical fixation of the pelvis or acetabulum, or both, in-hospital outcomes were not clearly related to hospital volume. After adjusting for potential confounders, in-hospital mortality was lowest for moderate volume hospitals, complication rates were lowest for small volume hospitals, and length of stay was shortest for high volume hospitals. However, the profile of lower complication rates, but
higher mortality rates in small volume centers compared to medium volume centers, is not readily understood based on the available information.

Disclosure Statement
None of the authors have any financial or other secondary gains of interest with respect to this research topic that might bias this work.

References