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A National Study of Trauma Level Designation and Renal Trauma Outcomes

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Abstract

Purpose—We examined the initial management of renal trauma and assessed patterns of management based on hospital trauma level designation.

Materials and Methods—The National Trauma Data Bank is a comprehensive trauma registry with records from hospitals in the United States and Puerto Rico. Renal injuries treated at a member hospital from 2002 to 2007 were identified. We classified initial management as expectant, minimally invasive (angiography, embolization, ureteral stent or nephrostomy) or open surgical management based on ICD-9 procedure codes. The primary outcome was use of secondary therapies.

Results—Of 3,247,955 trauma injuries in the National Trauma Data Bank 9,002 were renal injuries (0.3%). High grade injuries demonstrated significantly higher rates of definitive success with the first urological intervention at level I trauma centers vs other trauma centers (minimally invasive 52% vs 26%, p <0.001), and were more likely treated successfully with conservative management (89% vs 82%, p <0.001). When adjusting for other known indices of injury severity, and examining low and high grade injuries, level I trauma centers were 90% more likely to offer an initial trial of conservative management (OR 1.90; 95% CI 1.19, 3.05) and had a 30% lower chance of patients requiring multiple procedures (OR 0.70; 95% CI 0.52, 0.95).

Conclusions—Following multivariate analysis conservative therapy was more common at level I trauma centers despite the patient population being more severely injured. Initial intervention strategies were also more definitive at level I trauma centers, providing additional support for tiered delivery of trauma care.

Keywords

wounds and injuries; kidney; outcome assessment (health care); health facilities

Examination of national trends and metrics of medical care for renal trauma has historically been difficult because the literature is based on single institution case series that lack standardized outcomes.[1–7] The primary focus of such series has been on nephrectomy rates with little attention to other trauma outcomes. This is unfortunate because many other prognostic factors may impact the successful management of renal trauma.

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Concurrent with the evolution of trauma management has been the promotion of tiered delivery of trauma care that focuses on the transfer of more acutely injured patients to high level trauma centers.[8,9] Trauma hospitals in the United States are stratified into 5 levels of trauma care, with the most acute being level I and the lowest acuity designated level V. Standardized management of the trauma case via algorithms for care and triage to higher level centers is thought to result in improved outcomes. Recent analysis of outcomes at level I vs level II trauma centers demonstrated improved outcomes at level I centers among more severely injured patients.[10]

During the last 30 years there has been a rapid increase in the number of states with mature trauma systems from 2 to more than 35.[6,9] The National Trauma Data Bank, a voluntary, hospital based national trauma registry, has been used to examine the role of prognostic factors such as gender in trauma outcomes.[11] Few analyses have used this multicenter database to examine renal trauma outcomes.[12] We used the NTDB to determine if tiered delivery of trauma care results in improved renal trauma outcomes at level I trauma centers. All trauma level designations were assessed, and the outcomes used to assess renal trauma care were nephrectomy rate, initial trial of conservative management and efficacy of the initial intervention.

MATERIALS AND METHODS

The NTDB is a multi-institutional trauma registry data set detailing the treatment of more than 3 million injured persons in North America. Trauma admissions from participating level I to IV trauma centers throughout the United States, Canada and Puerto Rico are included in the NTDB. Our analysis included data from 2002 to 2007. A Certificate of Exemption (#07-8650-X/A) was obtained from the University of Washington Human Subjects Division.

The Abbreviated Injury Scale was used to code renal injuries in the NTDB. We mapped these injuries to American Association for the Surgery of Trauma renal injury grades as described by Moore et al (see Appendix).[13] Renal injuries were categorized by AAST grade as grade I—AIS code 541612, grade II—AIS code 541622, grade III—AIS code 541624, grade IV—AIS code 541626 and grade V—AIS code 541628.[14–16]

We used the methodology for converting AIS codes to AAST grade described by Kuan et al.[15] Patients who had AIS codes that could be mapped to AAST grades were included in the analysis while AIS codes that mapped to more than 1 AAST grade were excluded from study. Algorithms were created that allowed us to extract all cases with AIS codes identified and exclude those that mapped to more than 1 AAST grade. We also performed preliminary analyses of the excluded cases to determine if those excluded from our analysis due to coding reasons were different from the cohort we identified.

Patients were stratified according to initial management of renal injury into the 3 groups of 1) open renal surgery (ICD-9 codes for nephrectomy 55.5–55.54, partial nephrectomy 55.4, suture of kidney laceration/renorrhaphy 55.81, autotransplant 55.61, nephrotomy 55.01, or other open kidney operation 55.89), 2) MI procedure (ICD-9 codes for diagnostic renal angiography 88.45, selective renal angioembolization 38.86, ureteral stent 59.8, retrograde nephroureterogram 87.74, percutaneous nephrostomy tube 55.02, 55.03, 55.92 and 55.93, and ureteroscopy 56.31) or 3) conservative management (no active intervention). A trial of conservative management was defined as no active intervention within the first 24 hours after hospital admission. Concurrent nonurological procedures were not included in the analysis if they did not relate to the urological outcome.

Demographic and injury specific variables stratified by trauma level designation were compared in unadjusted and adjusted analyses. The success of each initial management strategy (surgical, minimally invasive and conservative therapy) was examined. We analyzed the success of initial management stratified by trauma level designation for low (AAST grades I to III) and high grade (AAST grade IV or V) renal injuries. Conservative management was defined as not undergoing a procedure during the first 24 hours of hospital admission. Patients who did not require active urological intervention during the index hospitalization were specifically noted. We categorized MI surgery as successful if it was not followed by any subsequent urological intervention. Surgical success was more difficult to quantify. After AAST grade I to IV renal injury, open surgery was considered successful if additional surgery was not required and nephrectomy was avoided during the initial open surgical intervention. For AAST grade V renal injuries open surgery was considered successful if additional surgery was not required. Nephrectomy for AAST grade V injuries was not considered treatment failure.

Predictors of nephrectomy, selective use of conservative management and success of initial management were evaluated using multivariate logistic regression analyses with a priori adjustment for patient age, gender, race, ISS and AAST kidney injury grade. In these analyses trauma center designation was categorized as level I vs any other level. For unadjusted analyses t tests were used to compare binary outcomes while chi-square analyses were performed for categorical variables. Adjusted analyses were performed using multivariate logistic regression analyses with robust standard errors. All p values were 2-sided with significance set at $p < 0.05$. Statistical analyses were performed using STATA® v11.0.

RESULTS

There were 18,348 patients with renal injuries available for analysis in the NTDB (table 1). Of these injuries 9,002 mapped to an AAST renal grade and the remaining injuries did not map to an AAST renal grade as discussed. To examine for possible bias among the group that was excluded because the cases did not map to an AAST grade, we performed a t test comparing the groups that matched to those that did not match to an AAST grade. Those cases that did not map to an AAST grade had significantly lower ISS scores (19.01 vs 21.9), but did not have significantly different death rates, age, gender, LOS, ICU days or trauma center level status.

After excluding subjects from analysis who did not have trauma center level identified, 6,290 renal injuries were categorized as initial conservative therapy (5,374, 85.4%), open renal surgery (643, 10.2%) or MI surgery (273, 4.3%). Mean age and gender were similar across trauma level designation. However, far fewer patients were treated at level III to IV trauma centers than at level I and II trauma centers (table 1). The population representation in each region of the United States was not equal. Therefore, this was included in our regression model to account for potential bias. Race differed significantly across trauma center level designation, with black and Hispanic patients more commonly treated at higher level centers that were more likely to have a university affiliation. Blunt renal trauma predominated and the majority of renal trauma cases were low grade.

Level I trauma centers treated more severely injured patients because median ISS was higher than at nonlevel I trauma centers. However, there was no difference in hypotension (systolic blood pressure less than 90 mm Hg) in the emergency department. The hospital LOS and intensive care unit LOS increased significantly with increasing trauma center level status. Nephrectomy rates and in-hospital mortality were similar across trauma center level designation despite the greater severity of injuries treated at level I centers. Despite these

differences, level I centers were more likely to use an initial 24-hour period of conservative management. Furthermore, level I centers were also significantly more likely to use less invasive interventions such as angioembolization.

The success of initial management based on trauma center level status for low and high grade injuries is shown in table 2. Conservative, minimally invasive and open procedures were more commonly successful for high grade injuries when performed at level I trauma centers than at nonlevel I centers. Among patients with low grade renal injury those treated with open surgery fared better at nonlevel I trauma centers (27 at level I center, 59% successful vs 114 at nonlevel I center, 80% successful). However, among patients with low grade injuries 41% of those treated with open surgery at nonlevel I trauma centers underwent nephrectomy vs 27% of those treated at level I centers.

Multivariate logistic regression was used to examine the success of initial therapy, the need for multiple procedures and the overall rates of nephrectomy (table 3). Level I trauma center designation was associated with a 90% increase in the odds of receiving a 24-hour trial of conservative management independent of other covariates. Furthermore, patients eventually undergoing nephrectomy at level I trauma centers had a 135% increased likelihood of undergoing an initial 24-hour trial of conservative management vs those treated at nonlevel I trauma centers (OR 2.35; 95% CI 1.35, 4.08; data not shown). Penetrating trauma was associated with 51% lower odds of initial conservative management. The odds of nephrectomy increased as AAST renal trauma grade increased.

The odds of nephrectomy did not vary by trauma center level designation, independent of other factors in the model (table 3). However, median ISS was higher at level I trauma centers (table 1). Multiple urological procedures were less likely to be performed at level I trauma centers.

DISCUSSION

To our knowledge this is the first report to examine the effect of trauma level designation on renal trauma care and acute outcomes. Our analysis of renal trauma using the NTDB supports the tiered delivery of trauma care after renal injury. Among high grade renal injuries (AAST grades IV and V) level IS centers were more successful in the initial management of renal trauma across all 3 initial management strategies (conservative, MI and open surgical).

Several factors from our analysis support the tiered delivery of renal trauma care. Mortality rates after renal trauma are not significantly higher at level I centers despite evidence that patients are sicker (decreased Glasgow coma score, increased LOS, increased ISS and longer ICU LOS). Nevertheless, nephrectomy rates at level I and level II trauma centers were comparable. Furthermore, initial therapy for renal trauma was more likely to be successful after high grade renal injury as evidenced by our findings that the overall need for multiple procedures was 30% lower at level I trauma centers. The reduced likelihood of multiple procedures at level I centers occurred despite the fact that level I centers more commonly attempted an initial trial of conservative therapy. Potential reasons for this success at level I trauma centers include an increased frequency of high grade renal injuries and better access to fully staffed trauma ICUs capable of providing acute trauma care.

Regionalization of overall trauma care via tiered delivery of trauma care has been proven to be successful.[8,17] Such studies have noted that regionalized trauma care at level I trauma centers compared to nontrauma centers provided more efficient trauma care and reduced mortality. Unfortunately to our knowledge there have not been any studies published exploring outcomes at trauma centers for organ specific trauma. Despite this limitation we

assert that examining the outcome of renal trauma at level I to IV trauma hospitals is important. For example, a higher rate of nephrectomy after renal exploration for renal trauma was discovered following a population based analysis of renal trauma outcomes from acute care hospitals than from other studies derived from level I trauma centers (64% vs 14% to 20%).[18–20]

Based on our findings the transfer of high grade renal injuries (AAST grades IV and V) to level I trauma centers should be considered to increase the efficiency of renal trauma care and to limit unnecessary interventions. While there is support in the medical literature for efficiency and improved outcomes for general trauma at level I centers, the specific reason for this advantage is unknown and thought to be multifactorial.[8,17] Such an impact of patient volume has been shown to positively impact other urological outcomes.

A recent study assessing trauma outcomes at level I and level II trauma centers in Ohio initially did not demonstrate a difference in mortality.[10] However, when adjusted for injury severity, mortality rates were lower at level I centers. As in our study unadjusted differences between level I and level II centers were most pronounced in terms of injury severity, yet did not reveal a difference in mortality. Once adjusted for more severe injuries, there was improved survival at level I trauma centers. Like our previous work from the NTDB this work also showed no overall impact of trauma center status on nephrectomy rate.[16]

A few issues regarding our analysis of renal injuries from the NTDB deserve mention. There was a longer overall LOS and ICU LOS at level I trauma centers. We speculate that this difference may partly be explained by a 90% higher rate of initial trial of conservative therapy at level I trauma centers but it could just as likely be due to myriad other factors. Another concern is the finding that initial surgical therapy was more successful at nonlevel I trauma centers after low grade renal injury. However, when examining outcomes in patients with low grade injuries, 41% of patients treated with open surgery at nonlevel I trauma centers underwent nephrectomy vs 27% of those treated at level I centers (data not shown). Given the lower rate of initial conservative therapy we suspect that the majority of these patients were taken to the operating room for other concomitant abdominal injuries. Unfortunately we do not have information regarding surgeon knowledge of renal injury via preoperative radiographic imaging or intraoperative 1-shot excretory urography. Regardless of this result, previous studies have repeatedly demonstrated that surgical intervention is rarely indicated after AAST grade I to III renal injuries.[21–24]

The limitations of the NTDB are not insignificant. This data set is hospital based rather than population based. Furthermore, it is impossible to control for all possible sources of confounding. While the NTDB is a significant improvement compared to single institution series, there is likely selection bias as well because level I and II centers are overrepresented in the NTDB. Finally, there is a significant (17%) number of patients in the NTDB for whom the trauma center level status was not reported. We dealt with this issue by excluding this group from our analysis. However, should the missing data be nonrandomly missing we would have confounded our analysis. Finally, the coding algorithms in STATA v.11 that allowed us to extract renal injuries that mapped to AAST grades excluded a significant portion of the renal injuries that mapped to more than 1 AAST grade. Inclusion of these cases was thought to introduce potential selection bias in the analysis if there was nondifferential omission that was not identified.

Despite the limitations of the NTDB, our analysis provides a strong argument for tiered delivery of renal trauma care. Conservative therapy was more common at level I trauma centers despite the more severely injured patient population. Nephrectomy rates did not differ from those at non-level I centers despite admitting a more acutely injured population.

Lastly, initial intervention strategies were also more definitive at level I centers, providing additional support for tiered delivery of trauma care.

Abbreviations and Acronyms

AAST	American Association for the Surgery of Trauma
AIS	Abbreviated Injury Scale
ICU	intensive care unit
ISS	Injury Severity Score
LOS	length of stay
MI	minimally invasive
NTDB	National Trauma Data Bank

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Table 1

Study sample characteristics

	Level 1 Trauma Center	Level II Trauma Center	Level III–IV Trauma Center	p Value*
No. pts	5,169	1,928	213	
Mean age (SD)	31.10 (17.2)	31.45 (17.5)	35.22 (19.4)	0.135
No. gender (%):				
F	1,385 (27)	524 (27)	57 (27)	0.025
M	3,773 (73)	1,404 (73)	155 (73)	
No. race (%):				
White	2,886 (58)	1,294 (69)	168 (81)	<0.0001
Black	1,052 (21)	245 (13)	24 (12)	
Hispanic	719 (14)	237 (13)	10 (4.8)	
Other	313 (6.3)	98 (5.2)	5 (2.4)	
No. hospital university affiliation (%)	4,102 (79)	272 (14)	57 (27)	<0.0001
No. geographical location (%):				
Midwest	1,348 (26)	517 (27)	78 (37)	<0.0001
Northeast	397 (7.7)	25 (1.3)	1 (0.5)	
South	2,332 (45)	965 (51)	79 (37)	
West	924 (18)	406 (21)	52 (24)	
Missing	162 (3.1)	15 (0.78)	3 (1.4)	
No. trauma mechanism (%):				
Blunt	4,171 (81)	1,667 (87)	189 (89)	<0.0001
Penetrating	986 (19)	255 (13)	24 (11)	
Other	11 (0.2)	6 (0.3)	0	
No. AAST renal injury grade (%):				
I	1,448 (28)	692 (36)	81 (38)	<0.0001
II	1,652 (32)	500 (26)	68 (32)	
III	1,006 (20)	349 (18)	32 (15)	
IV	798 (15)	268 (14)	21 (10)	
V	265 (5.1)	119 (6.2)	11 (5.2)	
Hospital course:				
Median ISS (IQR)	22.0 (20)	20.1 (21)	19.5 (23)	0.212
Mean admission Glasgow Coma Scale (SD)	12.5 (4.5)	12.4 (4.6)	12.7 (4.5)	0.001
Mean days LOS (SD)	12.2 (17.3)	9.4 (12.6)	9.8 (14.2)	0.046
Mean days ICU LOS (SD)	5.3 (11.3)	4.4 (9.2)	4.3 (9.9)	0.0001
No. systolic blood pressure less than 90 mm Hg (%)	551 (11)	194 (10)	11 (5)	0.068
No. nephrectomy (%)	430 (8)	162 (8)	9 (4)	0.103
No. angiography (%):				
Diagnostic angiography	49 (45)	15 (52)	4 (80)	0.0074
Angioembolization	60 (55)	14 (48)	1 (20)	
No. conservative management (%):				0.002
Initial 24 hrs	559 (12)	178 (10)	13 (6.4)	

	Level 1 Trauma Center	Level II Trauma Center	Level III–IV Trauma Center	p Value*
Entire index admission	4,117 (87)	1,616 (90)	189 (93)	
No. pt disposition (%):				
In-hospital mortality	588 (12)	214 (11)	16 (8)	0.056
Home with or without home health	3,323 (64)	1,290 (67)	125 (59)	<0.0001
Rehabilitation/skilled nursing facility	843 (16)	272 (14)	42 (20)	
Transfer	101 (2)	73 (4)	22 (10)	
Other	204 (4)	54 (3)	4 (2)	
Missing	76 (2)	9 (1)	2 (1)	

* Chi-square for binary and categorical, simple linear regression for continuous variables.

Table 2

Likelihood of success with initial management strategy

	Level I Trauma Center	Other	p Value*
No. low grade (%):			
Conservative	3,002 (99)	1,329 (99)	0.61
MI	52 (87)	134 (85)	0.80
Open surgery	16 (59)	91 (80)	0.05
No. high grade (%):			
Conservative	734 (89)	309 (82)	0.0089
MI	69 (52)	18 (26)	<0.001
Open surgery	371 (89)	165 (85)	0.13

*Chi-square test, injuries with trauma center level unknown excluded.

Table 3

Multivariate logistic regression model of initial expectant management before nephrectomy, the need for multiple interventions and requirement for nephrectomy for all renal trauma injury grades

	Initial Conservative Management OR (95% CI)	Need for Multiple Procedures OR (95% CI)	Nephrectomy Performed OR (95% CI)
Level I (vs all other levels)	1.90 (1.19, 3.05)	0.70 (0.52, 0.95)	1.00 (0.79, 1.26)
Region (vs Midwest):			
Northeast	0.13 (0.01, 1.27)	0.54 (0.23, 1.27)	0.70 (0.37, 1.34)
South	0.69 (0.41, 1.16)	0.89 (0.64, 1.23)	1.46 (1.11, 1.91)
West	1.36 (0.65, 2.85)	0.65 (0.39, 1.08)	0.54 (0.36, 0.81)
Trauma mechanism (vs blunt):			
Penetrating	0.49 (0.29, 0.82)	0.51 (0.37, 0.71)	4.58 (0.14, 42.0)
Kidney AAST grade (vs grade I):			
II	0.91 (0.19, 4.39)	1.08 (0.56, 2.07)	2.76 (1.25, 6.07)
III	0.85 (0.22, 3.25)	1.13 (0.58, 2.18)	9.09 (4.30, 19.2)
IV	1.04 (0.30, 3.71)	2.18 (1.18, 4.02)	57.4 (27.9, 118)
V	0.62 (0.17, 2.34)	1.51 (0.74, 3.03)	223 (104, 478)

Adjusted for age, gender, race and ISS.

APPENDIX

AAST Organ Injury Severity Score for Renal Trauma

Grade	Type	Description
I	Contusion	Microscopic or gross hematuria, urological studies normal
	Hematoma	Subcapsular, nonexpanding without parenchymal laceration
II	Hematoma	Nonexpanding perirenal hematoma confined to renal retroperitoneum
	Laceration	Parenchymal depth of renal cortex less than 1.0 cm without urinary extravasation
III	Laceration	Parenchymal depth of renal cortex greater than 1.0 cm without collecting system rupture or urinary extravasation
IV	Laceration	Parenchymal laceration extending through renal cortex, medulla and collecting system (positive urine extravasation)
	Vascular	Main renal artery or vein injury with contained hemorrhage
V	Laceration	Completely shattered kidney
	Vascular	Avulsion of renal hilum that devascularizes kidney

Advance 1 grade for bilateral injuries up to grade III.