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### Authors

Keihani, Sorena  
Xu, Yizhe  
Presson, Angela P  
et al.

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# Contemporary management of high-grade renal trauma: Results from the American Association for the Surgery of Trauma Genitourinary Trauma study

Sorena Keihani, MD, Yizhe Xu, MS, Angela P. Presson, PhD, James M. Hotaling, MD, Raminder Nirula, MD, Joshua Piotrowski, MD, PhD, Christopher M. Dodgion, MD, Cullen M. Black, Kaushik Mukherjee, MD, Bradley J. Morris, Sarah Majercik, MD, Brian P. Smith, MD, Ian Schwartz, MD, Sean P. Elliott, MD, Erik S. DeSoucy, DO, Scott Zakaluzny, MD, Peter B. Thomsen, Bradley A. Erickson, MD, Nima Baradaran, MD, Benjamin N. Breyer, MD, Brandi Miller, DO, Richard A. Santucci, MD, Matthew M. Carrick, MD, Timothy Hewitt, Frank N. Burks, MD, Jurek F. Kocik, MD, Reza Askari, MD, and Jeremy B. Myers, MD, for the Genito-Urinary Trauma Study Group, Salt Lake City, Utah

<b>BACKGROUND:</b>	The rarity of renal trauma limits its study and the strength of evidence-based guidelines. Although management of renal injuries has shifted toward a nonoperative approach, nephrectomy remains the most common intervention for high-grade renal trauma (HGRT). We aimed to describe the contemporary management of HGRT in the United States and also evaluate clinical factors associated with nephrectomy after HGRT.
<b>METHODS:</b>	From 2014 to 2017, data on HGRT (American Association for the Surgery of Trauma grades III-V) were collected from 14 participating Level-1 trauma centers. Data were gathered on demographics, injury characteristics, management, and short-term outcomes. Management was classified into three groups—expectant, conservative/minimally invasive, and open operative. Descriptive statistics were used to report management of renal trauma. Univariate and multivariate logistic mixed effect models with clustering by facility were used to look at associations between proposed risk factors and nephrectomy.
<b>RESULTS:</b>	A total of 431 adult HGRT were recorded; 79% were male, and mechanism of injury was blunt in 71%. Injuries were graded as III, IV, and V in 236 (55%), 142 (33%), and 53 (12%), respectively. Laparotomy was performed in 169 (39%) patients. Overall, 300 (70%) patients were managed expectantly and 47 (11%) underwent conservative/minimally invasive management. Eighty-four (19%) underwent renal-related open operative management with 55 (67%) of them undergoing nephrectomy. Nephrectomy rates were 15% and 62% for grades IV and V, respectively. Penetrating injuries had significantly higher American Association for the Surgery of Trauma grades and higher rates of nephrectomy. In multivariable analysis, only renal injury grade and penetrating mechanism of injury were significantly associated with undergoing nephrectomy.
<b>CONCLUSION:</b>	Expectant and conservative management is currently utilized in 80% of HGRT; however, the rate of nephrectomy remains high. Clinical factors, such as surrogates of hemodynamic instability and metabolic acidosis, are associated with nephrectomy for HGRT; however, higher renal injury grade and penetrating trauma remain the strongest associations. ( <i>J Trauma Acute Care Surg</i> . 2018;84: 418–425. Copyright © 2018 Wolters Kluwer Health, Inc. All rights reserved.)
<b>LEVEL OF EVIDENCE:</b>	Prognostic/epidemiologic study, level III; Therapeutic study, level IV.
<b>KEY WORDS:</b>	Renal trauma; renal injury grading; wounds and injuries; trauma centers; multicenter study.

Renal injury is an important cause of morbidity after trauma, and the kidney is the most common organ in the genitourinary system to be injured during trauma.<sup>1</sup> Renal injury occurs

in about 1% to 5% of all traumatic injuries.<sup>1–4</sup> Most renal injuries are low-grade (American Association for the Surgery of Trauma [AAST] grades I and II), expectantly managed with

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From the Division of Urology, Department of Surgery (S.K., J.M.H., J.B.M.), Division of Epidemiology, Department of Internal Medicine (Y.X., A.P.P.), Department of Surgery (R.N.), University of Utah, Salt Lake City, Utah; Department of Urology (J.P.), Department of Surgery (C.M.D.), University of Wisconsin, Milwaukee, Wisconsin; Division of Acute Care Surgery (C.M.B., K.M.), Loma Linda University Medical Center, Loma Linda, California; Division of Trauma and Surgical Critical Care (B.J.M., S.M.), Intermountain Medical Center, Murray, Utah; Division of Trauma and Surgical Critical Care (B.P.S.), Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania; Department of Urology (I.S., S.P.E.), Hennepin County Medical Center, University of Minnesota, Minneapolis, Minnesota; Department of Surgery (E.S.D.), Division of Trauma, Acute Care Surgery, and Surgical Critical Care, Department of Surgery (S.Z.), University of California Davis Medical Center, Sacramento, California; Department of Urology (P.B.T., B.A.E.),

University of Iowa, Iowa City, Iowa; Department of Urology (N.B., B.N.B.), University of California-San Francisco, San Francisco, California; Department of Urology (B.M., R.A.S.), Detroit Medical Center, Detroit, Michigan; Medical City Plano (M.M.C.), Plano, Texas; Department of Urology (T.H., F.N.B.), Oakland University William Beaumont School of Medicine, Royal Oak, Michigan; Department of Surgery (J.F.K.), East Texas Medical Center, Tyler, Texas; and Division of Trauma, Department of Surgery (R.A.), Brigham and Women's Hospital, Boston, Massachusetts. Address for reprints: Sorena Keihani, MD, Division of Urology, Department of Surgery, University of Utah School of Medicine, 30, North 1900, Salt Lake City, UT 84132; email: Sorena.keihani@hsc.utah.edu.

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observation, and have minimal morbidity.<sup>5</sup> Although more controversial, management of high-grade renal trauma (HGRT) [AAST grades III-V] has also transitioned to become predominantly nonoperative and for most hemodynamically stable patients the American Urological Association Guidelines recommend observation.<sup>6</sup> Despite recommendations for a mostly nonoperative approach, a considerable proportion of patients with HGRT still undergo operative management, usually with nephrectomy. Nephrectomy is the most common surgical procedure performed in the initial management of renal trauma and about 8% of all renal injuries are managed in this way.<sup>3,7,8</sup> According to the National Trauma Data Bank (NTDB) nephrectomy is common for HGRT—24% and 57% of grade IV and V injuries undergo nephrectomy, respectively.<sup>8</sup>

The reasons for continued reliance on nephrectomy after renal trauma are not well established; this may be in part related to trauma characteristics (e.g., shock, ongoing bleeding, adjacent bowel injury), lack of familiarity with renorrhaphy, or expediency. One of the reasons that research on HGRT is limited is the rarity of this injury. Thus, studies often span decades of care where there was a transition from operative approaches to expectant or observational management.<sup>9</sup> More contemporary studies of the NTDB also reflect a high rate of nephrectomy, even for grade I and II renal injuries; however, there may be inaccuracies in the initial grading of the injuries leading to the inaccurate conclusion that nephrectomy occurs even for low grade renal injuries.<sup>8</sup> Several studies have tried to establish risk factors associated with nephrectomy;<sup>10–14</sup> however, they are generally limited by small sample size and retrospective single-center design. These studies also establish associations with nephrectomy, which are based on radiologic findings rather than a combination with important clinical parameters, such as shock, concomitant injuries, and mechanism of trauma.<sup>11,12,15,16</sup> The above factors have limited the strength of evidence-based guidelines. Thus, the optimal management of HGRT remains controversial.

Timely and accurate identification of patients who would benefit from intervention is paramount in management of renal injuries. Thus, multi-institutional prospective studies are needed to assess the contemporary management of renal trauma and evaluate radiologic and clinical factors associated with nephrectomy. This information is critical in developing and improving renal trauma guidelines. The primary goals of the current study are twofold: (1) to assess the current rates of intervention after HGRT and (2) to evaluate the clinical factors associated with nephrectomy in this patient population.

## METHODS

### Patients

This study was conducted as a collaborative effort of the AAST and the Genito-Urinary Trauma Study Group (full study sites and collaborators' information is available at: <http://www.turnresearch.org/page/aast-gu-trauma-study-group-author-list-renal-trauma>).

The study was designed as a prospective observational study to gather data on all adult patients presenting with HGRT admitted to the participating centers between February 1, 2014, and February 1, 2017. Fourteen Level I trauma centers participated

in the study after obtaining institutional review board approval. Patients were excluded if they were younger than 18 years, had low-grade renal injuries (AAST grade I or II), underwent an urgent open surgery in an outside hospital without clinical and imaging data available, or were dead before arrival at the receiving hospital.

### Data Collection

The AAST TraumaSource centralized database platform was used for data collection. The following data were gathered: patients' demographics, admission and discharge/death dates, mechanism of injury (blunt: road traffic accidents, falls, sport-related, assault; penetrating: gunshot/shotgun wound, stab wound), Injury Severity Score (ISS), admission vital signs (systolic blood pressure [SBP], heart rate [HR], temperature, nadir SBP in first 4 hours after admission), Glasgow Coma Scale (GCS), number and type of blood products received in the first 24 hours, admission laboratory values (hematocrit/hemoglobin, lactate, base deficit), renal injury grade (III/IV/V), concomitant injuries and corresponding AAST grades if applicable, renal-related interventions (angiography/angioembolization, nephrectomy, partial nephrectomy, renorrhaphy, renal packing, ureteral stenting, nephrostomy tube placement, perirenal drain placement), initial and follow-up imaging studies, complications, and readmission. Data were reviewed at multiple stages and quality checks were performed regularly to assure accurate and complete data entry by all sites.

### Definitions

Injuries were graded based on the AAST Organ Injury Scale for renal trauma.<sup>17</sup> Grades III-V injuries were considered as HGRT. Computed tomography scan findings were used to grade the injuries when available; in patients undergoing immediate surgery, surgical findings were used to grade renal injuries in the absence of imaging studies. Management was defined as:

1. Expectant management: observation of the patient, including bed rest, serial hemoglobin check, follow-up imaging—no renal-related interventions (i.e., no endoscopic, minimally invasive, or open interventions or surgeries).
2. Conservative/minimally invasive management: performing renal angioembolization or renal vascular stent placement, endoscopic (e.g., ureteral stenting) or percutaneous procedures (e.g., nephrostomy tube or perirenal drain placement).
3. Open operative management: performing renal-related interventions after laparotomy, including nephrectomy, partial nephrectomy, renorrhaphy, and renal packing for bleeding control. Laparoscopic and robot-assisted procedures, although rarely used after acute trauma, were included under this category if they led to one of the above-mentioned procedures.

A single patient could have received more than one intervention during the management course and the most invasive renal-related procedure defined the patient's management group. Interventions less than 4 hours from admission to the study hospital were considered immediate interventions. An admission or nadir SPB less than 90 mm Hg (within 4 hours of hospital arrival) was defined as shock. Heart rate greater than 100 beats/min at admission was defined as tachycardia. Receiving greater than 10 packed red blood cells (PRBC) was defined

as massive transfusion. Concomitant injury was defined as presence of any of the following injuries: solid organ (liver, spleen, pancreas), gastrointestinal, spinal cord, bladder, major vascular, and pelvic fracture. Comorbidities were defined as having a medical history of any of the following: diabetes, myocardial infarction, stroke, congestive heart failure, peripheral vascular disease, chronic obstructive pulmonary disease, end-stage renal disease, and cirrhosis. Severe base deficit was defined as having a base deficit lower than  $-6$  mEq/L.

## Statistical Analysis

Patients were summarized as count (%) for categorical variables and mean, standard deviation (SD) for continuous

variables. Categorical variables were compared by groups using  $\chi^2$  tests or Fisher's exact tests when appropriate; continuous variables were compared using Wilcoxon ranked sum test if the distribution was skewed, or using  $t$ -test if the distribution was approximately normal. Statistical significance was assessed at the 0.05 level, and all tests were two-tailed. Univariate logistic mixed effect models with clustering by facility were used to analyze associations between proposed risk factors and nephrectomy. Clinical relevance, in combination with the results from the univariate analyses, were used to choose appropriate variables for the multivariate logistic mixed effect model. The number of covariates in the adjusted model was limited by the number of nephrectomy events in the data set.

**TABLE 1.** Demographics and Management of HGRT (AAST III-V) Split by Mechanism of Injury

	Total, N = 431	Blunt, n = 308	Penetrating, n = 123	<i>p</i> *
Age: mean (SD), y	34.4 (16.5)	36.7 (18.2)	28.7 (9.0)	<b>0.002</b>
BMI (SD), kg/m <sup>2</sup>	27.1 (6.3)	27.2 (6.3)	27.0 (6.4)	0.74
Male sex, n (%)	341 (79%)	230 (75%)	111 (90%)	<b>&lt;0.001</b>
ISS, mean (SD)	26.2 (13.3)	27.3 (13.9)	23.5 (11.5)	<b>0.02</b>
HR on admission, mean (SD), beats/min	94.2 (24.1)	94.5 (23.1)	93.6 (26.7)	0.64
Tachycardia on admission, n (%)	167 (39%)	122 (40%)	45 (38%)	0.60
SBP on admission, mean (SD), mm Hg	123.1 (28.6)	123.6 (26.8)	122.1 (32.7)	0.74
Shock, n (%)	112 (26%)	80 (26%)	32 (26%)	0.93
Hemoglobin on admission, mg/dL	12.4 (2.4)	12.5 (2.2)	11.9 (2.7)	<b>0.02</b>
PRBC transfusion in the first 24 h, n (%)	198 (48%)	116 (40%)	82 (68%)	<b>&lt;0.001</b>
Platelets transfusion in the first 24 h, n (%)	82 (20%)	50 (17%)	32 (28%)	<b>0.02</b>
FFP transfusion in the first 24 h, n (%)	124 (30%)	69 (24%)	55 (47%)	<b>&lt;0.001</b>
Lactate, mean (SD), mmol/L	3.8 (3.2)	3.6 (3.1)	4.2 (3.3)	0.17
GCS score, mean (SD)	12.8 (4.1)	12.7 (4.2)	13.1 (3.8)	0.37
Concomitant injuries, n (%) **	310 (72%)	203 (66%)	107 (87%)	<b>&lt;0.001</b>
Comorbidity, n (%) †	43 (10%)	35 (11%)	8 (7%)	0.14
AAST renal grade, n (%)				<b>0.01</b>
III	236 (55%)	179 (58%)	57 (46%)	
IV	142 (33%)	100 (32%)	42 (34%)	
V	53 (12%)	29 (9%)	24 (20%)	
Renal injury side				0.12
Left	202 (47%)	152 (49%)	49 (40%)	
Right	206 (48%)	138 (45%)	68 (56%)	
Bilateral	23 (5%)	18 (6%)	5 (4%)	
Management, n (%)				
Expectant	300 (70%)	243 (79%)	57 (46%)	<b>&lt;0.001</b>
Conservative intervention	47 (11%)	37 (12%)	10 (8%)	0.24
Open operative	84 (19%)	28 (9%)	56 (46%)	<b>&lt;0.001</b>
Interventions, n (%)				
Renal angioembolization	28 (6%)	24 (8%)	4 (3%)	0.13
Ureteral stenting	29 (7%)	22 (7%)	7 (6%)	0.59
Nephrectomy	55 (13%)	22 (7%)	33 (27%)	<b>&lt;0.001</b>
Other ‡	68 (16%)	21 (7%)	47 (38%)	<b>&lt;0.001</b>
Length of hospital stay, mean (SD), d	10.5 (11.3)	10.2 (11.7)	11.3 (10.4)	<b>0.03</b>
Mortality	33 (8%)	23 (7%)	10 (8%)	0.80

\* Comparisons made between blunt and penetrating trauma, bold numbers indicate statistically significant at  $p < 0.05$  level.

\*\* Defined as presence of any concomitant injury, including: solid organ, gastrointestinal, spinal cord, major vascular, and pelvic fracture.

† Defined as having a medical history of any of the followings: diabetes, myocardial infarction, stroke, congestive heart failure, peripheral vascular disease, chronic obstructive pulmonary disease, end-stage renal disease, or cirrhosis.

‡ Other interventions include: partial nephrectomy, renorrhaphy, renal packing, perirenal drain placement, and percutaneous nephrostomy. Patients could have received more than one intervention.

AAST, The American Association for the Surgery of Trauma; SD, standard deviation; BMI, body mass index.

## RESULTS

A total of 431 adult HGRTs were recorded. Patients' characteristics, clinical/laboratory findings at the time of admission, and management options are presented in Table 1. The mean age was 34.4 years (SD, 16.5; range, 18–92 years). Overall, 341 (79%) patients were male. Mechanism of injury was blunt in 308 (71%), with motor vehicle collision the leading etiology (61%) followed by falls and sport-related injuries (11% each). Of the 123 penetrating injuries, 97 (79%) were gunshot wounds, and 26 (21%) were stab wounds. The mean ISS was 26.2 (SD: 13.3) and about half of the patients had an ISS greater than 25 (i.e., very severe injury). The majority of the patients (72%) had concomitant injuries (mostly liver [37%] and splenic [29%] injuries). Overall, 112 (28%) patients had shock during their emergency room admission (including 46 patients who presented in shock). Laparotomy was performed in 169 (39%) patients; 132 laparotomies were immediate (<4 hours from admission).

Renal injuries were graded as III, IV, and V in 236 (55%), 142 (33%), and 53 (12%) of the patients, respectively. Overall, 300 (70%) patients were observed without any renal-related intervention (expectant management). Forty-seven (11%) patients underwent conservative or minimally invasive interventions including: renal angioembolization (n = 28), percutaneous nephrostomy or perirenal drain placement (n = 23), and ureteral stenting for urinary extravasation (n = 29); some patients received more than one intervention. A total of 84 patients (19%) underwent open renal-related surgeries: 55 (13%) patients underwent nephrectomy, 23 (5%) were treated with partial nephrectomy or renorrhaphy, and 10 (2%) patients were managed with renal packing for bleeding control with or without

**TABLE 2.** Univariate Logistic Regression Model for Predicting Nephrectomy After HGRT

	OR (95% CI)	p*
Age, y	0.98 (0.96–1.00)	0.09
AAST renal grade		
III and IV	1.00 (reference)	—
V	29.11 (13.29–63.75)	<0.001
Mechanism of injury		
Blunt	1.00 (reference)	—
Penetrating	4.82 (2.62–8.84)	<0.001
ISS	1.05 (1.03–1.07)	<0.001
Tachycardia (yes/no)	2.92 (1.60–5.32)	<0.001
Shock (yes/no)	2.05 (1.12–3.76)	0.02
Hemoglobin at admission, mg/dL	0.88 (0.79–0.98)	0.02
Massive PRBC transfusion (yes/no)	18.75 (8.64–40.66)	<0.001
PLT transfusion in the first 24 h, (yes/no)	7.45 (3.97–13.97)	<0.001
Concomitant injuries (yes/no)	5.64 (1.98–16.03)	<0.001
Base deficit		
≥ -6 mEq/L	1.00 (reference)	—
<-6 mEq/L	3.12 (1.48–6.58)	0.003
Lactate, mmol/L	1.14 (1.03–1.25)	0.009
GCS	0.93 (0.81–1.07)	0.33
Comorbidity (yes/no)	0.88 (0.33–2.37)	0.80

\* Bold numbers indicate statistical significance at  $p < 0.05$  level.  
PLT, platelet.

**TABLE 3.** Multivariate Logistic Regression Model for Predicting Nephrectomy After HGRT

	OR (95% CI)	p*
AAST renal grade		
III and IV	1.00 (reference)	—
V	34.09 (11.15–104.19)	<0.001
Mechanism of injury		
Blunt	1.00 (reference)	—
Penetrating	4.87 (1.70–13.95)	0.003
Shock (yes/no)	1.56 (0.56–4.34)	0.40
Hemoglobin at admission, mg/dL	0.92 (0.73–1.17)	0.49
Concomitant injuries (yes/no)	3.24 (0.52–20.02)	0.21
Lactate, mmol/L	1.05 (0.88–1.24)	0.60

\* Bold numbers indicate statistical significance at  $p < 0.05$  level.

partial nephrectomy or renorrhaphy. The nephrectomy rate was 1 (0.4%) of 236, 21 (15%) of 142, and 33 (62%) of 53 for grades III, IV, and V, respectively. Thirty-eight (69%) nephrectomies were performed within 4 hours, and 49 (89%) were performed within 24 hours of patient admission at the receiving hospital.

Interventions, including nephrectomy, were more common for penetrating injuries compared with blunt trauma. Patients with penetrating injuries were younger, had higher rate of concomitant injuries, and received more units of blood products in the first 24 hours after admission. Of the 55 nephrectomies, 33 (60%) were performed for penetrating injuries. The overall nephrectomy rate was 27% for penetrating injuries versus 7% for blunt ( $p < 0.001$ ). Patients with penetrating injuries had a higher number of grade IV and V renal injuries ( $p = 0.01$ ). Patients with penetrating trauma had longer hospital stays (median, 9 days; IQR, 4–16) compared with those with blunt trauma (median, 6 days; IQR, 3–13;  $p = 0.03$ ). The rate of mortality was not different between penetrating and blunt trauma.

In univariate analyses, higher renal AAST grade, penetrating injury, higher ISS, and presence of concomitant injuries were significantly associated with undergoing nephrectomy. Also, clinical measures, such as tachycardia, shock, higher lactate level, severe base deficit, and massive transfusion were associated with higher odds of nephrectomy (Table 2). In multivariable analysis, only renal injury grade (odds ratio [OR], 34.09; 95% confidence interval [CI], 11.15–104.19) and penetrating type of injury (OR, 4.87; 95% CI, 1.70–13.95) were significantly associated with undergoing nephrectomy (Table 3).

## DISCUSSION

Expectant/conservative management is currently the standard of care for low-grade renal trauma and is also recommended for most high-grade injuries when patients are hemodynamically stable.<sup>6</sup> Our findings from this multicenter study, involving 14 Level I trauma centers across the United States, show that about 80% of high-grade renal injuries are managed expectantly or with conservative/minimally invasive approaches. However, nephrectomy is the most common intervention after HGRT with 15% of grade IV and 62% of grade V

injuries undergoing nephrectomy. Renal injury grade and penetrating injury are the strongest predictors for nephrectomy.

Using the NTDB renal injury data from 2002 to 2007, McClung et al.<sup>8</sup> reported nephrectomy rates to be 4.5% for grade III, 24% for grade IV, and 57% for grade V injuries. These rates were slightly lower compared with the 1998 to 2003 reports from the same database.<sup>14</sup> Our nephrectomy rates were lower for grades III (0.4%) and IV (15%), but slightly higher for grade V (62%). The differences in our study compared with the NTDB may reflect the changes in management of renal injuries during recent years and movement toward less invasive management, specifically for grade III and IV injuries.<sup>8</sup> The New England Trauma Consortium reported a nephrectomy rate of 21% (43/206) for grades IV and V renal injuries.<sup>18</sup> In comparison, this rate in our study was higher (28%; 54/195 grades IV and V). However, the main reason underlying this difference is the inclusion of penetrating trauma in our series, in contrast to the aforementioned study, which only included blunt injuries. When we only considered blunt injuries, the nephrectomy rate was lower (17%; 22/129) compared with that reported by the New England Trauma Consortium.

In the past, penetrating injuries were believed to be at a higher risk for bleeding. Some have recommended a lower threshold for exploration and intervention after penetrating renal trauma;<sup>19,20</sup> however, more recently, selective observation and a nonoperative approach has been shown to be feasible.<sup>21,22</sup> Similar to Davis et al.,<sup>10</sup> in our study, penetrating trauma was an independent predictor for nephrectomy even after adjusting for renal injury grade. We found the rate of nephrectomy after penetrating trauma was 27% (33/123). Similarly, in the NTDB, penetrating injuries had a much higher rate of nephrectomy compared with blunt injuries (26% vs. 5%).<sup>8</sup> One can hypothesize that acceleration/deceleration injuries arising from a blunt mechanism of trauma would injure the kidney at hypothetical “weak points” or natural lines of fracture, while a penetrating wound can cause a more “random” injury pattern depending on the object’s trajectory through the parenchyma. For this reason, penetrating injuries may have different parenchymal and vascular injury patterns compared with blunt injuries and require different management strategies. However, this theory has not been studied, and it remains unknown if higher nephrectomy rates in penetrating injuries reflect a more severe injury pattern to the kidney or merely a higher incidence of surgical exploration after penetrating trauma, which itself increases the likelihood of nephrectomy.

Decreasing renal exploration—when possible—might be the most important step in reducing nephrectomy rates. Kidneys, given their confined retroperitoneal location, have an innate tamponade mechanism to control excessive bleeding and urinary extravasation. When Gerota’s fascia is entered during renal exploration, the hematoma is no longer contained, and this may lead to more bleeding and the need for nephrectomy. In addition, uncontained urinary leak may compromise adjacent injury repair, such as bowel or pancreatic injury. Studies have shown that by merely using an institutional goal for nonoperative management when appropriate, nephrectomy rates decrease for grade III and IV renal trauma.<sup>23–26</sup> Similarly, others have shown that nephrectomy rates can be decreased by avoiding Gerota’s fascia exploration, even in the context of penetrating gunshot wounds.<sup>27</sup>

Surprisingly, findings from the NTDB show that 30% of grade I to III injuries, who had laparotomy in the first 24 hours after trauma, underwent nephrectomy.<sup>8</sup> Similarly, Shoobridge et al.<sup>28</sup> reported that all patients who proceeded to renal exploration underwent nephrectomy, although they used a higher threshold for open surgery and had overall lower rates of intervention. Our results also show that when an open operative intervention was performed, it often led to nephrectomy (65%) with very few cases of partial nephrectomy, renorrhaphy, or renal packing. This is in line with the NTDB data showing scarce use of these procedures.<sup>8</sup> In addition, Winters et al.<sup>29</sup> showed decreasing rates of renorrhaphy and partial nephrectomy over time, from 1988 to 2010. Part of this shifting trend may be attributable to a decline in overall kidney exploration rates, even for more severe injuries, as well as more common use of angioembolization and minimally invasive procedures. However, it appears that renal exploration, when performed, will end in nephrectomy in the majority of patients.<sup>2</sup>

Although it is arguable that some “severe” injuries in hemodynamically unstable patients should better be treated with immediate open surgery, experience from Europe suggests that immediate angioembolization by trained and accessible radiologists can be feasible regardless of patients’ hemodynamic status.<sup>30</sup> Conservative management with renal angioembolization can help to decrease surgical exploration and nephrectomy.<sup>31</sup> Some studies have estimated that 10% to 40% of high-grade renal injuries undergo angioembolization,<sup>32–34</sup> however, in our study, renal angioembolization was used in only 6% of HGRT. Greater reliance on expedient and selective angioembolization may be a route to decrease nephrectomy rates although there is a high rate of repeat angioembolization and also occasional need for secondary open surgeries.<sup>35–37</sup>

Recognizing the clinical and radiologic factors that are associated with nephrectomy is important in understanding and identifying modifiable factors that may decrease nephrectomy rates. Previous efforts have been generally limited to retrospective data from single centers and also were often based on data spanning decades of care.<sup>10,13,28</sup> In our univariate analyses, we found that factors, such as shock and tachycardia, receiving blood products, and surrogates of metabolic acidosis (e.g., lactate and severe base deficit), were significantly associated with risk of nephrectomy. The presence of concomitant injuries was another significant factor that can be a surrogate for injury severity. However, this may also indicate higher rates of laparotomy for nonrenal injuries that subsequently lead to renal exploration and nephrectomy. Renal injury grade remains the most powerful predictor of nephrectomy and along with a penetrating mechanism were the only factors that remained significant associations when controlling for shock and its proxies.

This study has a number of strengths and limitations. This is one of the few multi-institutional studies on renal trauma and is based on contemporary management strategies for HGRT. We used data collection tools prospectively designed for this study and were able to gather data from multiple centers across the United States over a 3-year period. Extensive clinical and imaging data were gathered at the time of admission, which enabled us to perform a detailed analysis using targeted data in comparison with other studies using administrative data. One limitation of our study is follow-up data and complications after the first

admission. We cannot comment on the number of patients who needed additional interventions or developed long-term complications after their discharge. This is an inherent limitation of most trauma studies as the patients seen in Level I trauma centers can be from different geographic areas, and many are transferred to these centers and will not seek follow up at the same facility.<sup>18</sup> Renal injury grades were provided by each center, and although all used the AAST grading system, there may be inconsistencies in grading of the injuries between centers and also between different providers. As another inherent limitation of multicenter observational studies, management was not standardized at different study sites, and there are likely significant differences among these centers in management of HGRT and other factors, such as predominance of blunt versus penetrating injury mechanisms. However, this reflects the real-world overall trends and rates of different management strategies across the country. Prospective multi-institutional controlled trials are needed to compare different management strategies and would elevate the level of evidence underlying management recommendations after renal trauma.

## CONCLUSION

Expectant and conservative management is currently used in about 80% of high-grade renal injuries; however, there is still a high rate of nephrectomy. Clinical factors, such as surrogates of hemodynamic instability and metabolic acidosis, are associated with nephrectomy for high-grade renal injury; however, higher renal injury grade and penetrating trauma remain the strongest predictors of nephrectomy.

## AUTHORSHIP

J. B. M., R. N., J. M. H., A. P. P., and S. K. designed the study. A. P. P., Y. Z., S. K., and J. B. M. participated in data analysis and data interpretation. J. B. M. and S. K. drafted the article. J. P., C. M. D., X. L., K. M., B. J. M., B. P. S., I. S., S. P. E., E. S. D., S. Z., P. B. T., B. A. E., B. N. B., G. M., B. M., R. A. S., M. M. C., T. H., F. N. B., J. F. K., R. A., S. K., and J. B. M. participated in the data collection and revisions for this article. J. B. M. and J. M. H. provided critical revisions for this article. All the authors read and approved the final submission.

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## DISCLOSURE

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## DISCUSSION

**DR. MICHAEL COBURN** (Houston, Texas): Thank you, Dr. Spain, Dr. Coimbra, members and guests. I congratulate the authors on an excellent presentation and on a very well-written manuscript. These data were prospectively collected from 14 participating Level I trauma centers.

You should know that this study is one of a growing number coming out of the work of “TURNS”, the Trauma and Urologic Reconstructive Network of Surgeons, which is a very well-organized, multi-institutional group of subspecialty-trained urologists whose work is focused on urologic trauma and reconstructive surgery.

The study group has NIH support and is really doing some great work and contributing importantly to the urologic trauma literature.

In this series, two-thirds of the patients underwent expectant management while 20 percent or 82 patients underwent open renal surgery. Of the latter group, two-thirds of these underwent nephrectomy, while only 28 percent underwent partial nephrectomy or renal reconstruction.

The majority of these nephrectomies were performed for penetrating trauma. These patients were younger, had more concomitant injuries, and more blood loss.

The observation that high grade of injury and penetrating trauma predict a higher likelihood of nephrectomy makes sense and is supported by NTDB and other data.

The data from the study are interesting. Are they important? The kidney is a paired organ. What difference does it make if one is removed?

Historically, when Dr. Jack McAninch began his career at San Francisco General Hospital the nephrectomy rate for renal trauma exploration dropped from over 50 percent to around 10 percent, presumably as the result of there being an interested, skilled, reconstructive urologist participating in the operative care of patients and focusing on renal salvage. It's a source of pride among trauma urologists to be able to repair all but the most severe and non-reconstructible renal injuries.

But what is the impact on patient morbidity and mortality of leaving the trauma patient with two versus one kidney? Is there any long-term impact on renal function? Do more patients who undergo nephrectomy develop renal failure, require dialysis or transplantation in the future?

The data to answer these questions are somewhat limited. But there are growing strong suggestions from the urologic literature that there are increased rates of renal dysfunction following nephrectomy, particularly in populations at risk - that is, those with diabetes, hypertension, limited access to medical care - our trauma population, in general.

Salvaging kidneys is important. And as long as it doesn't increase the morbidity and mortality of overall trauma outcome or of the initial laparotomy it is an important priority.

Three questions for the authors:

1. Considering the high likelihood of nephrectomy in patients undergoing renal exploration for trauma, would you endorse a non-operative or expectant approach for all hemodynamically stable high-grade renal injuries?

2. Does the participation of an engaged trauma urologist impact the likelihood of nephrectomy versus renal repair?

And, 3. How would you structure this prospective management study to really sort out which trauma patients require surgery and, also, where the expectant management approach may actually be harmful?

Thank you, again, to the Program Committee and congratulations to the authors on a superb presentation.

**Dr. Kimberly A. Davis** (New Haven, Connecticut): This was a very nicely presented study. I have one very quick question. You made a fairly rapid reference to a lack of use of angioembolization. Is that because these patients were already in the operating room undergoing laparotomy for other reasons, i.e., their penetrating trauma and/or associated injuries? Or are we truly not embolizing kidneys when we embolize livers and spleens all the time? Can you comment? Thank you.

**Dr. David J. Dries** (Saint Paul, Minnesota): Thank you for showing us a new standard for renal protection. I was struck



as you were tracing out the history of renal salvage from blunt and penetrating trauma that as we have improved our resuscitation of these patients we have also gotten better at salvaging kidneys.

As improved resuscitation buys time for other options in renal salvage, I ask you to share your thoughts with us regarding additional opportunities for renal salvage. For example, will angioembolization play a greater role as we are more effective in stabilizing these patients? Thank you.

**Dr. Thomas J. Schroepfel** (Colorado Springs, Colorado): You may have alluded to it and I missed it, but what was the indication for nephrectomy? If it's an expanding hematoma it's pretty clear, but once you open Gerota's fascia and get into bleeding the kidney often comes out. Please comment. Thanks.

**Dr. Charles E. Lucas** (Detroit, Michigan): More than 20 years ago Dr. Michael McGonigal presented our data from the Detroit Receiving Hospital and we concluded at the time that, if the kidney is functioning and not bleeding, leave the damned thing alone, regardless of the severity of injury. Needless to say, we were severely criticized, particularly from the San Francisco General Hospital group.

One of the questions that we answered at the time was that when you do operate, you usually take out the injured kidney, just like these authors described, and the renal function is worse after nephrectomy.

Using sophisticated methodology, we measured renal blood flow and renal blood flow distribution. This demonstrated reduced renal function and this contributed to a higher mortality rate. I congratulate the authors on this paper.

**Dr. Sorena Keihani** (Salt Lake City, Utah): Thank you, Dr. Coburn, and thank you to the audience for insightful comments and questions.

So I would like to start with a comment from Dr. Coburn regarding the value of saving the salvageable kidney.

This is very true that there is very little data available on long-term impacts of removing the kidney after trauma, so patients are at high risk of renal failure when they have a preexisting condition, as mentioned.

Also, unlike the renal transplant donors, trauma does not select for healthy patients who can always tolerate a lifetime living with a single kidney.

So, also, when the kidney is salvageable and functional it might actually help to have function of both kidneys to maximize patient recovery during the acute treatment.

So we recognize that nephrectomy is sometimes a lifesaving maneuver, especially in the presence of hypertension. But our data suggests that 60 percent of patients who underwent nephrectomy were not in hypertension and did not need massive transfusion.

So regarding Dr. Coburn's question about would we recommend non-operative or expectant management for stable, high grade trauma, absolutely. Our goal is to minimize nephrectomy rates when the kidney is salvageable.

So as urologists we believe that preserving kidney function is important and when damage control surgery can be used it's important to have imaging studies and more accurate evaluation and grading of the – accurate grading of the kidney before proceeding to nephrectomy or renal repair.

Regarding the question of engaging a urologist, decreased nephrectomy rates versus renal repair, yes. However, here is a limited number of trauma urologists with experience or interest in management of high-grade renal injuries.

There are a few centers that enjoy such a collaboration between trauma surgeons and urologists so we have to design studies that are applicable primarily to trauma surgeons rather than the few involved urologists.

Regarding the question from the audience about angioembolization, the rates significantly varied among different centers. We didn't have a standard protocol or a set protocol.

One thing that is worth mentioning is we need to clarify when angiography is done for renal injuries. So initially when we looked at our database we had a rate of 25 percent angiography.

But then when we looked at the angioembolization on that were specifically done for renal injuries, the rate came down to 6 percent. So we don't know why but that is what – that is the condition with our database.

And then about the predictors, the second question was about what do we need for successful management. We need good predictors.

We need both clinical and radiology predictors because many of these patients' Grade V injuries, Grade IV injuries, do not have initial imaging available. So we need good predictors, both clinical and imaging, to be able to say which patients would benefit from nephrectomy.

I think I answered the indications for nephrectomy with this one. And thank you for the last comment. I would say, yes, leave the damned thing alone.