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The American Association for the Surgery of Trauma renal injury grading scale: Implications of the 2018 revisions for injury reclassification and predicting bleeding interventions

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BACKGROUND: In 2018, the American Association for the Surgery of Trauma (AAST) published revisions to the renal injury grading system to reflect the increased reliance on computed tomography scans and non-operative management of high-grade renal trauma (HGRT). We aimed to evaluate how these revisions will change the grading of HGRT and if it outperforms the original 1989 grading in predicting bleeding control interventions.

METHODS: Data on HGRT were collected from 14 Level-1 trauma centers from 2014 to 2017. Patients with initial computed tomography scans were included. Two radiologists reviewed the scans to regrade the injuries according to the 1989 and 2018 AAST grading systems. Descriptive statistics were used to assess grade reclassifications. Mixed-effect multivariable logistic regression was used to measure the predictive ability of each grading system. The areas under the curves were compared.

RESULTS: Of the 322 injuries included, 27.0% were upgraded, 3.4% were downgraded, and 69.5% remained unchanged. Of the injuries graded as III or lower using the 1989 AAST, 33.5% were upgraded to grade IV using the 2018 AAST. Of the grade V injuries, 58.8% were downgraded using the 2018 AAST. There was no statistically significant difference in the overall areas under the curves between the 2018 and 1989 AAST grading system for predicting bleeding interventions (0.72 vs. 0.68, p = 0.34).

CONCLUSION: About one third of the injuries previously classified as grade III will be upgraded to grade IV using the 2018 AAST, which adds to the heterogeneity of grade IV injuries. Although the 2018 AAST grading provides more anatomic details on injury patterns and includes important radiologic findings, it did not outperform the 1989 AAST grading in predicting bleeding interventions. (*J Trauma Acute Care Surg.* 2020;88: 357–365. Copyright © 2019 American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Prognostic and Epidemiological Study, level III.

KEY WORDS: Renal trauma; organ injury scale; computed tomography; wounds and injuries; trauma centers; multicenter study.

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The American Association for the Surgery of Trauma (AAST) organ injury scale is the most commonly used tool to grade traumatic solid organ injuries, including renal trauma. Originally devised in 1989, the AAST renal injury grading was based on the anatomic findings usually encountered at the time of surgical exploration of the injured organ.[1] Although not designed to be a prognostic tool, subsequent studies showed a good correlation between higher grades of renal trauma and surgical interventions, mostly nephrectomy.[2–4] However, over the next several decades, it became evident that most renal injuries can be managed conservatively and nephrectomy is seldom justified except in the case of an unsalvageable kidney or hemodynamically unstable patients in extremis. This paradigm shift and a better understanding of different patterns in renal trauma stimulated a recent update in the grading system to create a more evidence-based predictive tool to guide management of renal trauma.[5]

In 2018, the AAST Patient Assessment Committee published revisions to the organ injury scales for spleen, liver, and kidney.[5] This was a much-anticipated update building on the previously proposed changes to the grading of high-grade renal trauma (HGRT)[6,7] and accounting for the importance of radiologic findings in decision making.[7–13] The 2018 AAST renal trauma grading uses the 1989 classification as a template and incorporates some computed tomography (CT) findings, such as active vascular bleeding and hematoma characteristics, in an attempt to better classify renal injuries and define operative goals.[5] Some of the major changes in the new grading system include: (1) adding vascular injuries and active bleeding within Gerota fascia under grade III injuries; (2) including segmental vascular injuries, segmental or complete parenchymal infarctions, and active bleeding beyond Gerota fascia under grade IV injuries; and (3) requiring active bleeding in the setting of completely devascularized kidney and also loss of parenchymal identification for shattered kidney under grade V injuries[14] (Table 1). However, not all the criteria in the original and revised grading systems are based on strong evidence, and the implications of these changes in injury reclassification have not yet been studied. Furthermore, it is unknown if these updates will lead to better prediction of bleeding control interventions in cases of HGRT.

We aimed to use our contemporary multi-institutional database of HGRT to study the implications of the 2018 AAST renal grading in injury reclassification, and also compare the ability of the original and the updated grading systems to predict whether a patient underwent any intervention to control bleeding from the kidney. Furthermore, we aimed to use our findings to suggest practical changes to the grading system to optimize its ability to evaluate the risk of bleeding interventions after HGRT.

PATIENTS AND METHODS

Study Design

Data for this study is from the phase 1 of the Multi-Institutional Genito-Urinary Trauma Study (http://www.turnsresearch.org/page/genito-urinary-trauma-study-miguts-renal),[15] which is a collaborative effort supported by the AAST multi-institutional trials committee, in conjunction with the Trauma and Urologic Reconstruction Network of Surgeons (TURNS.org). Details on the renal trauma study protocol and data collection have been previously published.[13,15,16] In brief, phase 1 of the study was a multi-institutional, prospective study that collected data on HGRT (defined as AAST grades III to V) from 14 Level I trauma centers across the United States between 2014 and 2017.

For this study, only HGRT patients who underwent a diagnostic CT scan after renal trauma were included. Patients who underwent immediate surgery without prior imaging were excluded. We also excluded patients who had injury patterns not

TABLE 1. The Original 1989 and Revised 2018 AAST Organ Injury Scales for Grading Renal Trauma*

Injury Grade	1989 AAST Original Grading	2018 AAST Revised Grading
I	– Parenchymal contusion with microscopic or gross hematuria with normal urologic studies – Subcapsular, nonexpanding hematoma without parenchymal laceration	– Subcapsular hematoma and/or parenchymal contusion without laceration
II	– Nonexpanding perirenal hematoma confined to renal retroperitoneum – Renal parenchymal laceration <1 cm depth without urinary extravasation	– Perirenal hematoma confined to Gerota fascia – Renal parenchymal laceration <1 cm depth without urinary extravasation
III	– Renal parenchymal laceration >1.0 cm depth without collecting system rupture or urinary extravasation	– Renal parenchymal laceration >1.0 cm depth without collecting system rupture or urinary extravasation – Any injury in the presence of a kidney vascular injury or active bleeding contained within Gerota fascia
IV	– Parenchymal laceration extending through renal cortex, medulla, and collecting system (positive urinary extravasation) – Main renal artery or vein injury with contained hemorrhage	– Parenchymal laceration extending into urinary collecting system with urinary extravasation – Renal pelvis laceration and/or complete ureteropelvic disruption – Segmental renal vein or artery injury – Active bleeding beyond Gerota fascia into the retroperitoneum or peritoneum – Segmental or complete kidney infarction(s) due to vessel thrombosis without active bleeding
V	– Completely shattered kidney – Avulsion from renal hilum that devascularizes kidney	– Main renal artery or vein laceration or avulsion of hilum – Devascularized kidney with active bleeding – Shattered kidney with loss of identifiable parenchymal renal anatomy

*Adapted from Moore et al. Organ injury scaling: spleen, liver, and kidney. J Trauma. 1989; 29(12): 1664–1666.1[1] and Kozar et al. Organ injury scaling 2018 update: Spleen, liver, and kidney. J Trauma Acute Care Surg. 2018; 85(6): 1119–1122.[5]

recognized in the 1989 AAST grading system. Data were gathered on demographics, injury characteristics, radiologic variables, and management. Details on radiology data extraction have been published previously.[13] All deidentified CT scans were uploaded to a secure web-based Orthanc[17] server for central review. Two radiologists, blinded to the intervention data and patient outcomes, independently reviewed the initial CT scans in order to extract injury specifics and renal injury grades. Follow-up scans and those obtained after interventions were not used in grading the renal injuries or adjusting the grades. All injuries were regraded based on the definitions provided in the 1989[1] and the 2018[5] versions of the AAST organ injury scale for renal trauma. Injuries were considered as ungradable if the injury pattern was not captured using one or both of the grading systems and thus comparing the grades was not possible (e.g., ungradable injuries using the 1989 AAST grading if parenchymal devascularization or vascular injuries are present without bleeding or visible lacerations). An initial training set of 20 CT scans from renal trauma patients was used to assure a common understanding of the study terminology and renal trauma grading and to achieve substantial agreement between reviewers in test cases (kappa >0.6) as values below this threshold indicates inadequate agreement between the readers.[18] After measuring initial interradiologist agreements, the scans were rereviewed to reach a consensus on discordant findings. Thus, only one grade was assigned to each renal injury. For continuous variables, the average of the two measurements was used. Input from a third reviewer was used to resolve disagreements. In cases of bilateral renal injury, the worst injury with the highest AAST grade was used to assign injury grade.

Definitions

Bleeding interventions were defined as surgical or endovascular interventions for bleeding control from a renal source and included: nephrectomy, partial nephrectomy, renorrhaphy, renal packing, and renal angioembolization. Hypotension/shock was defined as systolic blood pressure of 90 mm Hg or lower anytime during the first 4 hours from admission. Vascular contrast extravasation (VCE) was defined as the presence of contrast accumulated outside of the renal parenchyma demonstrated on arterial or venous phase CT scan. Hematoma rim distance was measured on the axial CT planes and was defined as the longest perpendicular distance from the renal parenchymal border to the hematoma border within the boundaries of superior and inferior kidney margins.[9,13] Pararenal hematoma was defined as hematoma extending beyond the aorta on the left or inferior vena cava on the right or extending inferior to the aortic bifurcation into the pelvis.[13] Depth of laceration was measured as the length of the deepest laceration in the axial plane in centimeters.

Statistical Analysis

Values are reported as percentages for categorical variables and mean (standard deviation) or median (25th to 75th interquartile ranges [IQR]) for continuous variables as appropriate. Descriptive statistics were used to assess reclassifications of injuries using different grading systems, and to compare the grades as provided by the participating centers, as well as the grades based on the 1989 and 2018 AAST grading for renal trauma.

Weighted Kappa analysis (with symmetric quadratic weighting) using a bootstrapped, bias-controlled method[19,20] was used to measure the agreement between the grades provided by the centers and the grades provided upon rereading the CT scans by our radiologists. Agreement was interpreted based on the kappa coefficient ranges and descriptions provided by McHugh as none (0–0.20), minimal (0.21–0.39), weak (0.40–0.59), moderate (0.60–0.79), strong (0.80–0.90), and almost perfect (above 0.90).[18]

Mixed effect Poisson regression models, with clustering by facility and robust estimator for error, were used to measure the predictive power of each classification system in univariable and multivariable models adjusted for age, sex, and Injury Severity Score. The areas under the curves (AUCs) and their 95% confidence intervals (CIs) were compared using the algorithm proposed by DeLong et al. for paired samples.[21] Statistical analyses were conducted in STATA 15 (Stata Corp, College Station, TX) using two-tailed tests and a 0.05 significance level.

RESULTS

There were 431 patients with HGRT in the database. A total of 322 patients were included after excluding those who did not undergo an initial CT scan before intervention (n = 105) and those with ungradable injuries (n = 4). Mean age was 34.8 ± 16.4 years, and mechanism of trauma was blunt in 80%. Baseline characteristics of patients as well as renal injury grades and radiologic variables are summarized in Table 2.

As submitted by the participating trauma centers into the centralized database, renal injuries were graded as III, IV, and V in 60%, 33%, and 7%, respectively. Upon reading the CT scans and regrading the injuries according to the 1989 original AAST grading, injuries were grade III or lower in 78%, grade IV in 17%, and grade V in 5%. The kappa agreement between the grades submitted by centers and those provided by the radiologists upon regrading of the injuries was weak (kappa: 0.50, 95% CI, 0.40–0.60). Overall, 27% of injuries were downgraded, 5% were upgraded, and 68% remained the same grade upon regrading (Supplemental Digital Content, Table 1, http://links.lww.com/TA/B540).

Using the 2018 updated AAST grading, injuries were graded as III or lower, IV, and V in 52%, 45%, and 3%, respectively. Comparing the 2018 AAST grading to the 1989 original grading, 87 (27.0%) of injuries were upgraded, 11 (3.4%) were downgraded, and 224 (69.5%) were unchanged (Table 3). Of the injuries graded as III or lower using the 1989 AAST, 33.5% were upgraded to grade IV using the 2018 AAST grading. Of the injuries graded as IV using the 1989 AAST, the majority (96.3%) remained the same. Of the grade V injuries, 58.8% were downgraded using the 2018 AAST.

Overall, 46 patients underwent bleeding interventions, including 19 renal angioembolizations, 15 nephrectomies, and 12 other open procedures. When compared with grade III or lower, both grade IV (odds ratio [OR], 3.04; 95% CI, 1.43–6.45) and V (OR, 12.03; 95% CI, 2.52–57.53) injuries had higher odds of undergoing interventions in the 2018 AAST grading. For the 1989 AAST grading, only grade V (OR, 9.00; 95% CI, 2.78–29.20) had significantly higher odds for intervention compared with grade III injuries. The odds ratios from multivariable models adjusted for age, sex, and ISS are presented in Table 4. There was no statistically significant difference in the AUC between the

TABLE 2. Demographics, Clinical, and Radiologic Variables in Our Study Cohort of High-Grade Renal Trauma (AAST III-V) Patients

	Total, N = 322
Demographics	
Age, mean (SD), y	34.8 (16.4)
Body mass index (SD), kg/m^2	27.4 (6.5)
Male sex, n (%)	248 (76%)
Injury specifics	
Injury severity score, mean (SD)	25.0 (12.7)
Trauma mechanism, n (%)	
Blunt	259 (80%)
Penetrating	63 (20%)
Tachycardia on admission, n (%)	122 (38%)
Hypotension/shock, n (%)	74 (23%)
Hemoglobin on admission, mg/dL	12.7 (1.9)
PRBC transfusion in the first 24 h, n (%)	116 (36%)
GCS score, median (IQR)	15 (14–15)
Concomitant injuries, n (%) *	216 (67%)
Length of hospital stay, median (IQR), d	6 (3–12)
Mortality	13 (4%)
AAST renal injury grade	
AAST grades as submitted by centers, n (%)	
III	194 (60%)
IV	107 (33%)
V	21 (7%)
1989 original AAST grades, n (%)	
I-III	251 (78%)
IV	54 (17%)
V	17 (5%)
2018 updated AAST grades, n (%)	
I-III	167 (52%)
IV	146 (45%)
V	9 (3%)
Radiologic variables	
VCE, n (%)	73 (23%)
Hematoma rim diameter, median (IQR), cm	1.6 (0.8–2.9)
Hematoma rim diameter ≥3.5 cm, n (%)	64 (20%)
Laceration depth, median (IQR), cm	1.9 (1.5–2.6)
Laceration depth ≥ 2.5 cm, n (%)	84 (26%)
Hematoma extent, n (%)	
None/subcapsular	42 (13%)
Perirenal	160 (50%)
Pararenal	120 (37%)

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

SD, standard deviation; IQR, 25th–75th interquartile range; PRBC, packed red blood cells; GCS, Glasgow Coma Scale; VCE, vascular contrast extravasation.

2018 AAST and 1989 AAST grading in predicting the bleeding interventions (0.72; 95% CI, 0.64–0.79 vs. 0.68; 95% CI, 0.59–0.76, p = 0.34) (Fig. 1).

DISCUSSION

Our findings show that using the 2018 AAST grading system, about a third of the injuries previously classified as grade III will be upgraded to grade IV, and more than half the injuries previously graded as V will be downgraded. Both grade IV and V injuries in the 2018 AAST grading system have higher odds of undergoing interventions compared with grade III. However, the two grading systems do not differ in their ability to predict bleeding control interventions after renal trauma.

The first noteworthy finding from this study was the weak agreement (kappa coefficient, 0.50) between the grades submitted by the centers into the study database and those obtained after reading the CT scans by our study team and regrading the injuries. This might be due to the marginal distribution of the observed injury grades (i.e., most injuries being graded as grade III), which can cause prevalence bias and unrepresentatively low kappa values.[22,23] However, this finding also brings into question the reproducibility of the AAST renal trauma grading by different readers and in different settings. We did not have details on how and by whom the renal injuries were graded at each center, but we would expect high variability in the readers' background and expertise although all centers are high-volume Level I trauma centers. The data collection phase of the study was done before the publication of the official 2018 updates on renal trauma grading; however, experts had previously proposed revisions to the original grading system.[6,7,24,25] Thus, some clinicians may have already adapted these changes in grading the injuries. However, the subtleties in the AAST renal trauma grading and some ambiguities in the definitions can make the grading systems highly subjective. In fact, Phan et al.[26] previously reported minimal agreement between three readers grading renal injuries using the 1989 AAST (kappa, 0.36; 95% CI, 0.25–0.47). Additionally, in their study, grading agreements were lower between different specialties compared with readers from the same specialty.

TABLE 3. Comparison of Renal Trauma Grades Using the 1989 and 2018 AAST Organ Injury Scales

		2018 AAST			
		Grade I-III	Grade IV	Grade V	Total
1989 AAST	Grade I–III	166 (51.5%)	84 (26.1%)	1 (0.3%)	251 (77.9%)
	Grade IV	0 (0%)	52 (16.1%)	2 (0.6%)	54 (16.8%)
	Grade V	1 (0.3%)	10 (3.1%)	6 (1.8%)	17 (5.3%)
	Total	167 (51.9%)	146 (45.3%)	9 (2.8%)	322 (100%)

Each cell represents the number of injuries and the percentage in relation to all patients.

TABLE 4. Multivariable Models Comparing the 1989 and 2018 AAST Renal Injury Grading for Prediction of Bleeding Interventions After HGRT

	Original AAST (1989)		Revised AAST (2018)	
Predictors	OR (95% CI)	p	OR (95% CI)	p
Renal injury grade				
Grade III	1.00 (Reference)	–	1.00 (Reference)	–
Grade IV	1.81 (0.78–4.22)	0.17	3.04 (1.43–6.45)	0.004
Grade V	9.00 (2.78–29.20)	<0.001	12.03 (2.52–57.53)	0.002
Age	1.01 (0.99–1.03)	0.40	1.01 (0.98–1.02)	0.78
Male sex	3.76 (1.30–10.88)	0.01	3.21 (1.14–9.06)	0.03
Injury Severity Score	1.02 (0.99–1.05)	0.09	1.03 (1.00–1.06)	0.03

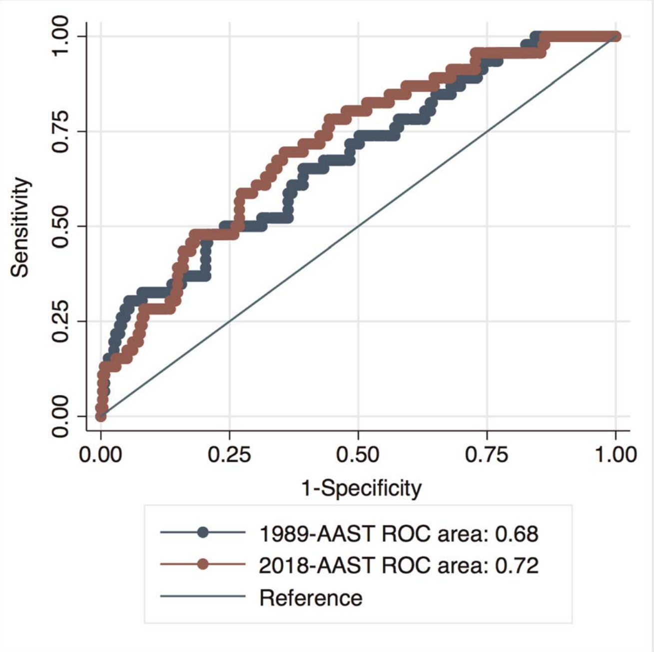

Figure 1. Receiver operating characteristics (ROC) curves for the 1989 (blue) and 2019 (red) AAST grading systems in predicting bleeding interventions. Diagonal line represents reference.

Pretorius et al.[27] reported slightly higher intradisciplinary and interdisciplinary agreements in grading the renal injuries; however, the agreement for specific AAST grades were still low especially for grade IV and V injuries. These findings demonstrate the interdisciplinary differences in interpretation of the grading system and the need for a more clear and objective grading system that will have higher reproducibility.

Upon regrading the injuries, 27% were downgraded compared with what was initially entered in our database. In fact, some injuries that were submitted as HGRT were regraded as grade I or II injuries, which suggests that overgrading is common. This might have implications when these data are used in central databases, such as the National Trauma Data Bank or in clinical research projects.[28] Our study, however, is based on the initial CT findings, and we cannot exclude the possibility that some injuries might have higher grades based on findings on follow-up imaging, such as urinary extravasation. Additionally, the AAST grading tables indicate to advance one grade for bilateral injuries up to grade III. We did not follow this recommendation when regrading the injuries as we do not see how a bilateral injury would increase risk of bleeding intervention, especially if the contralateral injury were lower grade. However, only 5% of our study group had bilateral injuries. Thus, we do not believe this accounted for the weak agreement observed between the submitted grades and our regrading.

Using the 2018 grading system, the most remarkable changes were upgrading of a third of injuries from grade III to IV and downgrading of about half of the injuries graded as V in the 1989 AAST grading. Inclusion of segmental renal artery or vein injury in the new definition of grade IV was the most common reason for this change in grades from III to IV. Renal segmental vascular injury is not part of the original 1989 grading and was first proposed by Buckley et al. in 2009 as a criterion for grade IV injuries.[6] However, this definition is vague and it is unclear if it refers to the renal vascular anatomy and the five segmental arteries supplying the kidney parenchyma or more generally to any vessels more distal than the main renal artery. Theoretically any wedge-shaped or partial infarction of the renal parenchyma can fulfill this definition and upgrade the renal injury to grade IV (Fig. 2*A* and *B*). Recently, Ballon-Landa et al.[29] compared the proposed 2009 revisions with the original grading and similar to our findings, they reported that 39% of patients with grade III injuries were upgraded. However, most segmental vascular injuries are not associated with increased risk of bleeding and including this criterion leads to increased heterogeneity for grade IV injuries with probably minimal improvement in its ability to differentiate the need for bleeding interventions. Malaeb et al.[30] studied grade IV patients with blunt segmental vascular injuries and reported that only 1 of the 51 patients with this injury pattern underwent major bleeding intervention. They concluded that the majority of patients with segmental vascular injuries can be successfully managed with observation alone and suggested that this injury pattern should be relegated to a lower grade.[30] For grade V injuries (59% downgraded), the changes were mostly due to the updated definition of "shattered kidney" (Fig. 2*C* and *D*) and also the requirement for active bleeding in a devascularized kidney to be considered grade V. We believe that this is a welcome change if grade V injuries are meant to represent the most severe renal injuries and correlate better with the need for bleeding interventions.

An ideal renal injury classification system should be based on well-defined and objective criteria.[25,27] Using clinically relevant radiographic findings that are easy to identify and measure can also help to decrease subjectivity in grading and facilitate reader training.[27] By including some of the important radiographic findings, such as active bleeding and hematoma characteristics in the grading system, the 2018 revisions provide a more clinically relevant classification of renal injuries (Table 1). However, some of the definitions remain vague and could be confusing.[31] For example, the 2018 AAST grading system defines vascular injuries as the presence of pseudoaneurysm or arteriovenous fistula. In the practical setting, trauma surgeons and urologists use the term "vascular injury" in reference to a more general collection of injury patterns including parenchymal infarctions, vascular dissections, and also lacerations of renal vessels that can lead to VCE.[24,32] Furthermore, the 2018 grading system still uses the term "shattered kidney" although it now requires the loss of identifiable parenchymal renal anatomy, which can downgrade some of the injuries previously classified as grade V. This definition is also vague and subjective and cannot be used as a definitive criterion. Not all kidneys with a shattered appearance are unsalvageable or will need nephrectomy.[33,34] Portions of intact and perfused renal parenchyma are common after blunt trauma, and although data are limited, these fragments may be viable and functional after the hematoma is absorbed.

A common dilemma in devising a renal trauma grading system is whether it is intended to provide anatomical characterization of an injury or to create an intervention prediction tool to help in management decisions.[30] While the 1989 original grading described anatomic findings, the current revisions include imaging findings that are associated with interventions and

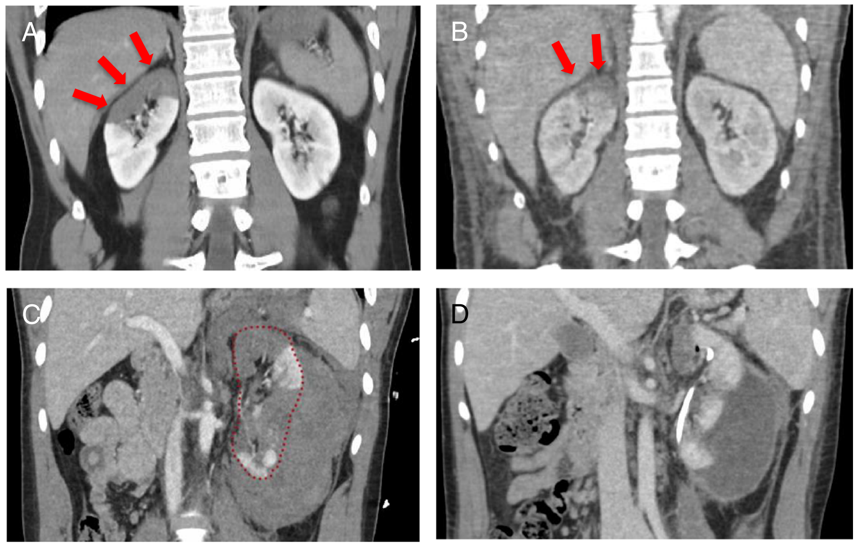

Figure 2. Grading changes between the 1989 and 2018 AAST renal grading systems. *A and B,* Initial trauma CT scan at admission (*A*) showing segmental vascular injury leading to segmental infarction in the right kidney after blunt trauma (red arrows). Follow-up image after 5 days (*B*) shows smaller area of infarction with resolving of the renal injury. The injury was graded as III according to the 1989 AAST grading due to parenchymal lacerations >1 cm without urinary extravasation (not shown) and was upgraded to grade IV according to the 2018 AAST grading due to segmental vascular injury and segmental infarctions without active bleeding. No renal-related interventions were done. *C and D*, Initial trauma CT scan at admission (*C*) showing parenchymal fragments and segmental devascularization of the left kidney with fluid collection around the kidney. The injury was graded as V according to the 1989 AAST grading indicating a "shattered kidney" and was downgraded to IV according the 2018 AAST grading due to segmental kidney infarctions without active bleeding and also because the renal parenchymal anatomy was still identifiable (red dotted line). Follow-up image at 1 month (*D*) shows more identifiable and vascularized renal parenchyma as well as walled-off fluid collection decreasing in size. No bleeding control renal-related interventions were performed; ureteral stent and perinephric drain were placed to help treat urinary extravasation and perirenal fluid collection.

might embrace the second goal of predicting management.[5] However, our study did not find statistically significant differences in the AUCs of the 1989 and 2018 grading systems in predicting bleeding interventions. This was in contrast with the findings of Ballon-Landa et al.[29] who compared the 1989 grading to the 2009 proposed revisions and found that the latter (which is in many ways similar to the 2018 grading system) outperforms the original grading system. Similar to this study, we found that grade IV injuries had higher odds for intervention in the 2018 grading system but not in the 1989 original grading system. We believe this is in part because many injuries are upgraded from III to IV using the revised definitions. This increases the heterogeneity of grade IV injuries while leaving very few interventions in grade III group, hence artificially increasing the odds ratio without actually providing a good distinction between who would or would not need an intervention within the grade IV group. In other words, if the only interventions occurred in grade IV injuries, then the AUC would be perfect for predicting interventions in grade IV compared with grade III, although any clinical utility of using the grading system to predict intervention would be eliminated. Regardless, upgrading injuries from grade III to IV and having more heterogeneity under grade IV injuries might have some clinical implications. Although the AAST renal injury grades are not designed to guide management decisions, some providers, especially in the setting of lower-tier trauma centers and limited experience with management of high-grade renal trauma, might use them as a crude guide to estimate the need for intervention. Thus, some patients that now will have grade IV injuries based on the 2018 AAST grading system might be considered to have "more severe" injuries and undergo stricter diagnostic or follow-up assessments or potentially receive unnecessary interventions.

As the renal trauma grading system was initially created based upon expert opinions, not all the criteria used are backed by strong evidence or are validated in large studies. For example, a laceration depth of 1 cm is used as the threshold for defining grade II versus grade III injuries (Table 1),[1,5] but has little practical diagnostic or prognostic utility. We previously showed that a laceration depth greater than 2.5 cm better predicted need for bleeding interventions.[13] In addition, it has been shown in multiple studies that a hematoma rim distance of 3.5 cm or greater and other hematoma characteristics, such as pararenal extension of hematoma are highly correlated with interventions for hemorrhage.[10–13] Thus, including these characteristics in a grading system could improve the ability of the AAST grading to better predict interventions.

In the current AAST grading system, the presence of any renal collecting system injury (positive urinary extravasation), will upgrade renal injuries to at least grade IV.[1,5] Since most cases of urinary extravasation heal spontaneously or with the help of ureteral stenting,[35] this information adds no benefit in predicting bleeding interventions for grade IV injuries. We believe that if a grade IV injury is to represent a severe injury with high probability for requiring bleeding control interventions, urinary extravasation should not be included as a grade IV criterion and may be more useful if provided as separate information. Of note, some other renal trauma classification systems, such as those from the Japanese Association for the Surgery of Trauma, provide the information on urinary extravasation in a separate appendix as a U (urinary) factor in comparison to the H (hemorrhage) factor.[36,37]

Our study has a number of strengths and limitations that are worth mentioning. As discussed, our regrading is based on the initial trauma CT scans and does not take into account potential follow-up findings that might change the initial grade. Additionally, we only included patients who had CT scans available for review; thus, patients who underwent immediate interventions without imaging were excluded from our analysis. We previously showed that the rate of bleeding control interventions in this excluded group was significantly higher compared with the included patients.[16] Our initial study protocol was designed to include patients with HGRT (defined as AAST grades III-V); thus, given the inconsistencies in grading, it is possible that some of the patients who would have been graded as III to V using the 1989 or 2018 grading system were not included in our database due to inaccuracies of center-based renal trauma grading. Our study is the first to evaluate the new 2018 revisions in a large multicenter setting and provide data-driven recommendations to improve the grading system. Two radiologists who were blind to the outcomes read all the images after an initial set of training, which minimizes the subjectivity of interpretations and adds to the credibility of our results.

CONCLUSION

The 2018 revisions to the AAST renal trauma grading provide more anatomic detail on injury patterns and include some radiologic findings important in the management of renal trauma. However, about a third of the injuries previously classified as grade III will be upgraded to grade IV using the new classification system, which adds to the heterogeneity of grade IV injuries. In our analysis, the 2018 renal trauma grading system did not outperform the original 1989 grading system in predicting intervention for renal hemorrhage. Further refinement of the grading system, such as adding hematoma size and separating collecting system injuries, could increase the utility of AAST grading as a predictive tool for the need for hemorrhage control.

AUTHORSHIP

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

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DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES

1. Moore EE, Shackford SR, Pachter HL, McAninch JW, Browner BD, Champion HR, Flint LM, Gennarelli TA, Malangoni MA, Ramenofsky ML, et al. Organ injury scaling: spleen, liver, and kidney. *J Trauma*. 1989;29(12):1664–1666.
2. Santucci RA, McAninch JW, Safir M, Mario LA, Service S, Segal MR. Validation of the American Association for the Surgery of Trauma Organ Injury Severity Scale for the Kidney. *J Trauma*. 2001;50(2):195–200.
3. Shariat SF, Roehrborn CG, Karakiewicz PI, Dhami G, Stage KH. Evidence-based validation of the predictive value of the American Association for the Surgery of Trauma kidney injury scale. *J Trauma*. 2007;62(4):933–939.
4. Kuan JK, Wright JL, Nathens AB, Rivara FP, Wessells H, American Association for the Surgery of Trauma. American Association for the Surgery of Trauma organ injury scale for kidney injuries predicts nephrectomy, dialysis, and death in patients with blunt injury and nephrectomy for penetrating injuries. *J Trauma*. 2006;60(2):351–356.
5. Kozar RA, Crandall M, Shanmuganathan K, Zarzaur BL, Coburn M, Cribari C, Kaups K, Schuster K, Tominaga GT, AAST Patient Assessment Committee. Organ injury scaling 2018 update: spleen, liver, and kidney. *J Trauma Acute Care Surg*. 2018;85(6):1119–1122.
6. Buckley JC, McAninch JW. Revision of current American Association for the Surgery of Trauma Renal Injury grading system. *J Trauma*. 2011;70(1):35–37.
7. Dugi DD 3rd, Morey AF, Gupta A, Nuss GR, Sheu GL, Pruitt JH. American Association for the Surgery of Trauma grade 4 renal injury substratification into grades 4a (low risk) and 4b (high risk). *J Urol*. 2010;183(2):592–597.
8. Myers JB, Brant WO, Broghammer JA. High-grade renal injuries: radiographic findings correlated with intervention for renal hemorrhage. *Urol Clin North Am*. 2013;40(3):335–341.
9. Nuss GR, Morey AF, Jenkins AC, Pruitt JH, Dugi DD III, Morse B, Shariat SF. Radiographic predictors of need for angiographic embolization after traumatic renal injury. *J Trauma*. 2009;67(3):578–582; discussion 82.
10. Figler BD, Malaeb BS, Voelzke B, Smith T, Wessells H. External validation of a substratification of the American Association for the Surgery of Trauma renal injury scale for grade 4 injuries. *J Am Coll Surg*. 2013;217(5):924–928.
11. Hardee MJ, Lowrance W, Brant WO, Presson AP, Stevens MH, Myers JB. High grade renal injuries: application of Parkland Hospital predictors of intervention for renal hemorrhage. *J Urol*. 2013;189(5):1771–1776.
12. Zemp L, Mann U, Rourke KF. Perinephric hematoma size is independently associated with the need for urological intervention in multisystem blunt renal trauma. *J Urol*. 2018;199(5):1283–1288.
13. Keihani S, Putbrese BE, Rogers DM, Zhang C, Nirula R, Luo-Owen X, Mukherjee K, Morris BJ, Majercik S, Piotrowski J, et al. The associations between initial radiographic findings and interventions for renal hemorrhage after high-grade renal trauma: results from the Multi-Institutional Genitourinary Trauma Study. *J Trauma Acute Care Surg*. 2019;86(6):974–982.
14. Chien LC, Vakil M, Nguyen J, Chahine A, Archer-Arroyo K, Hanna TN, Herr KD. The American Association for the Surgery of Trauma Organ Injury Scale 2018 update for computed tomography-based grading of renal trauma: a primer for the emergency radiologist. *Emerg Radiol*. 2019.
15. Keihani S, Xu Y, Presson AP, Hotaling JM, Nirula R, Piotrowski J, Dodgion CM, Black CM, Mukherjee K, Morris BJ, et al. Contemporary management of high-grade renal trauma: results from the American Association for the Surgery of Trauma Genitourinary Trauma study. *J Trauma Acute Care Surg*. 2018;84(3):418–425.
16. Keihani S, Rogers DM, Putbrese BE, Moses RA, Zhang C, Presson AP, Hotaling JM, Nirula R, Luo-Owen X, Mukherjee K, et al. A nomogram predicting the need for bleeding interventions after high-grade renal trauma: results from the American Association for the Surgery of Trauma Multi-Institutional Genito-Urinary Trauma Study (MiGUTS). *J Trauma Acute Care Surg*. 2019;86(5):774–782.

17. Jodogne S. The Orthanc ecosystem for medical imaging. *J Digit Imaging*. 2018;31(3):341–352.
18. McHugh ML. Interrater reliability: the kappa statistic. *Biochem Med (Zagreb)*. 2012;22(3):276–282.
19. Berry KJ, Johnston JE, Mielke PW Jr. Weighted kappa for multiple raters. *Percept Mot Skills*. 2008;107(3):837–848.
20. Reichenheim ME. Confidence intervals for the kappa statistic. *Stata J*. 2004; 4(4):421–428.
21. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics*. 1988;44(3):837–845.
22. Hallgren KA. Computing inter-rater reliability for observational data: an overview and tutorial. *Tutor Quant Methods Psychol*. 2012;8(1): 23–34.
23. Sabour S. Reproducibility of the American Association for the Surgery of Trauma scaling for renal injury: methodological issue to avoid misinterpretation. *Prog Urol*. 2018;28(5):239–240.
24. Stein DM, Santucci RA. An update on urotrauma. *Curr Opin Urol*. 2015; 25(4):323–330.
25. Chiron P, Hornez E, Boddaert G, Dusaud M, Bayoud Y, Molimard B, Desfemmes FR, Durand X. Grade IV renal trauma management. A revision of the AAST renal injury grading scale is mandatory. *Eur J Trauma Emerg Surg*. 2016;42(2):237–241.
26. Phan QB, Mourey E, Estivalet L, Delattre B, Bardet F, Chevallier O, Louis D, Aho LS, Loffroy R, Cormier L. Reliability and reproducibility of the American Association for the Surgery of Trauma scaling for renal injury and impact on radiologic follow-up. *Prog Urol*. 2018;28(1):12–17.
27. Pretorius EJ, Zarrabi AD, Griffith-Richards S, Harvey J, Ackermann HM, Meintjes CM, Cilliers WG, Zunza M, Szpytko AJ, Pitcher RD. Inter-rater reliability in the radiological classification of renal injuries. *World J Urol*. 2018; 36(3):489–496.
28. Wright JL, Nathens AB, Rivara FP, Wessells H. Renal and extrarenal predictors of nephrectomy from the national trauma data bank. *J Urol*. 2006;175(3 Pt 1): 970–975; discussion 5.
29. Ballon-Landa E, Raheem OA, Fuller TW, Kobayashi L, Buckley JC. Renal trauma classification and management: validating the revised renal injury grading scale. *J Urol*. 2019;202:994–1000.
30. Malaeb B, Figler B, Wessells H, Voelzke BB. Should blunt segmental vascular renal injuries be considered an American Association for the Surgery of Trauma Grade 4 renal injury? *J Trauma Acute Care Surg*. 2014;76(2):484–487.
31. Keihani S, Gross JA, Myers JB. RE: organ injury scaling 2018 update: spleen, liver, and kidney. *J Trauma Acute Care Surg*. 2019;87:998–999.
32. Elliott SP, Olweny EO, McAninch JW. Renal arterial injuries: a single center analysis of management strategies and outcomes. *J Urol*. 2007;178(6):2451–2455.
33. Fang C, Husainy MA, Huang D. A shattered kidney: a pitfall in imaging of renal trauma. *BMJ Case Rep*. 2015;2015. pii: bcr2015211496.
34. Spain DA, Berger Y, Boyarsky AH, Flancbaum LJ. Nonoperative management of bilateral shattered kidneys from blunt trauma. *Urology*. 1993;41(6):579–581.
35. Keihani S, Anderson RE, Fiander M, McFarland MM, Stoddard GJ, Hotaling JM, Myers JB. Incidence of urinary extravasation and rate of ureteral stenting after high-grade renal trauma in adults: a meta-analysis. *Transl Androl Urol*. 2018;7(Suppl 2):S169–S178.
36. Nishizawa S, Mori T, Shintani Y, Kohjimoto Y, Inagaki T, Hara I. Applicability of blunt renal trauma classification of Japanese Association for the Surgery of trauma (JAST). *Int J Urol*. 2009;16(11):862–867.
37. Keihani S, Anderson RE, Hotaling JM, Myers JB. Diagnosis and management of urinary extravasation after high-grade renal trauma. *Nat Rev Urol*. 2019;16(1):54–64.

DISCUSSION

FERNANDO J. KIM, M.D. (Denver, Colorado): Thank you very much, Chairman. I would like to thank the AAST for the great honor and opportunity to comment on this paper.

Thank you, Sorena. This is a great attempt, and I really commend you, and the 14 other institutions that collaborated with you, on this very important paper.

But let's remind ourselves that, in 1989, Dr. Moore and colleagues tried to create a scale injury in solid organs; that was based in anatomic findings and ultimately, triggered the curiosity and involvement of urologists to further study the renal trauma grading system.

This pioneering project allowed health care providers to understand each other when describing renal injuries in trauma patients. Also, the classification became important for research to create databases, coding and billing. This discussion is an opportunity to educate all of us including the radiologists so we can better manage our trauma patients.

During your presentation, you mentioned that the Grade IVs and Grade Vs are different and they are specific injuries. As you know, different grading systems have been proposed in the past to reclassified and differentiate the bleeding renal parenchymal injuries from collecting system injuries that may create urinomas.

Furthermore, you have shown that from the 322 patients with renal injuries using the AAST injury scale classification, one-third of patients were upgraded, 3 percent were downgraded, and about 70 percent remained unchanged. But not all Grade IIs or IIIs are equal. The anatomical injury may be the same but patients on blood thinners may have different outcomes and management. How do you propose to include these “different” Grade IIs trauma patients taking anticoagulants in your nomogram?

Finally, what is your dream classification? And how does this nomogram help the trauma team to predict patients that can benefit from surgical or minimally invasive embolization, or endoscopic ureteral stent placement?

I thank the AAST for including the urologists in the multi-institutional studies. This allow us to work together with trauma surgeons and provide a multi-specialty approach to the genitourinary trauma patients.

Thank you very much.

ROSEMARY A. KOZAR, M.D., Ph.D. (Baltimore, Maryland): I want to thank the authors for their important contributions to the literature. I'm one of the authors of the 2018 revision.

I think it's important to realize that this was our initial attempt at incorporating CT scan imaging into the grading system. Importantly, the grading system wasn't just for the kidney, and it had to be something that we were able to use for the spleen and liver as well as the kidney, which made it somewhat challenging.

As you suggested, the hematoma size may be important for the kidney but isn't really applicable so much to the liver and spleen, and that was part of the problem.

In terms of laceration, there are some machine learning capabilities that are being studied now that give us a volumetric assessment of laceration as opposed to just a simple size. This could be of help in all solid organs in the classifications. Again I thank the authors for their contributions.

SORENA KEIHANI, M.D. (Salt Lake City, Utah): Thank you so much. Thank you, Dr. Kim, for the nice summary of the history of the AAST grading, and also the insightful comments. Thank you, Dr. Kozar, for your work on the grading system and the comments.

I will start with Dr. Kozar's comment about this being an injury scaling system including spleen, kidney, and liver. So, it's challenging to come up with a terminology that encompasses all of these together. Another example are vascular injuries. Pseudoaneurysms, and AVF—arteriovenous fistulas—are now included as vascular injuries. Usually in terms of kidney trauma, we just refer to the more general term of vascular injury for all injury patterns, but I can see that it comes from the splenic or liver injuries mostly. So, that's definitely something that we need to work on to have organ grading systems that are more specific to that organ.

About Dr. Kim's question, what do we think about a better classification for renal injuries, I agree with you that the grading system was not devised to be a predictive tool. It was based on the surgical findings. It was based on anatomical findings at the time of surgery, at a time that conservative management was not the standard of care.

So, we think that, if we want to focus on bleeding interventions, maybe we just need to move to a nomogram, or to a predictive tool that takes into factor multiple clinical and radiologic factors to estimate the risk of bleeding in a patient.

And also, there have been studies about segmental vascular infarction, there have been studies that showed almost none of the patients with this injury pattern would need bleeding control interventions. So, including this injury pattern, kind of dilutes the Grade IV injuries.

This study was part of a bigger project looking at the contemporary management of renal trauma overall, and the management patterns in the United States. It was also an effort to find factors associated with bleeding after renal trauma to make a predictive tool, such as a nomogram. But more importantly, this is definitely a framework for building collaborations and designing meaningful prospective studies, which is the ultimate goal of these retrospective projects.

We believe that this will be part of a continuous quality improvement project, and we hope that the findings from this study will provide some of the evidence needed to improve the grading system in the future and management of renal trauma overall.

Thank you.