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Renal Trauma: When to Embolize?

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Abstract
Purpose of Review The management of solid organ injury continues to evolve from operative therapy to non-operative therapy with the highest success rates seen in the management of blunt renal trauma. Angio-embolization has emerged as an important modality to increase the success rate of non-operative management of kidney injuries.
Recent Findings There is a paucity of literature defining the optimal indications for renal embolization, but several retrospective reviews indicate the computed tomography findings associated with the need for renal embolization. Pseudoaneurysms, large perirenal hematomas with associated intravenous contrast extravasation, and arteriovenous fistulas strongly indicate the need for embolization, while discontinuity of Gerota's fascia, moderate hematomas, and medially located renal lacerations partially suggest that embolization will be required.
Summary The successful management of renal trauma is not solely dependent on the use of renal artery embolization.

Keywords Kidney laceration · Perirenal hematoma · Contrast extravasation · Embolization · Perirenal hematoma rim distance · Gerota's fascia

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Introduction

The kidneys are the largest and most frequently injured component of the genitourinary system; however, they are relatively protected from harm due to their anatomic position within the body. The kidneys are buried deep in the retroperitoneum, partially shielded by the spinal column and the 10th and 11th ribs, the psoas muscles, perinephric fat, and encased in the dense Gerota's fascia. Accordingly, renal trauma affects only about 1.4–3.25 % of trauma patients and makes up about 10 % of traumatic abdominal injuries [1]. The vast majority of renal injuries are due to blunt trauma with only about 16 % of injuries, a result of penetrating trauma [2]. Due to their relatively protected location, isolated renal injuries are relatively infrequent and kidney injuries typically occur in the setting of polytrauma. Similar to injuries to the spleen and liver, the management of kidney injuries has radically changed over the last two decades from one of operative interventions to non-operative management; however, the kidneys are extremely vascular and receive the greatest blood flow per gram of tissue of any intra-abdominal organ which complicates their non-operative management.

Hemodynamically unstable patients with hemorrhage attributable to the kidney should be taken to the operating room for laparotomy and nephrectomy, but identifying the kidney as the sole source of hemorrhagic shock is difficult. Focused assessment with ultrasound for trauma (FAST) has become the diagnostic study of choice to detect significant intraperitoneal blood in unstable patients; however, it is extremely limited in its ability to detect renal hemorrhage [3]. Prior to the advent of FAST, diagnostic peritoneal lavage was commonly performed to identify intra-abdominal hemorrhage; however, this test, like FAST, is also limited in its detection of retroperitoneal bleeding.

Fortunately, most trauma patients can be stabilized with fluid resuscitation in order to undergo imaging with multidetector computed tomography (MDCT). Owing to its high resolution and the relative ease of obtaining images, MDCT with intravenous contrast has become the "gold standard" to detect renal trauma [4]. MDCT delineates the location, extent and nature of renal lacerations, the size and character of associated hematomas, the presence of intravenous contrast extravasation (ICE), and urinary extravasation as well as other associated injuries. These findings allow for the accurate staging of renal injuries in order to prioritize and formulate treatment plans.

In 1989, Moore et al. classified renal injuries in an organ injury scale (OIS) promulgated by the American Association for the Surgery of Trauma (AAST) that enumerated renal injuries in a scale from 1 to 5 according to the type, location, and severity of the injury [5] (Table 1). This scale was subsequently validated as an accurate tool to predict the need for surgical intervention in large retrospective databases, while others demonstrated that it was able to correctly determine the need for nephrectomy. Non-operative management is indicated in all hemodynamically stable patients according to both European and American guidelines, and the literature documents success rates over 90 % for grades I–III injuries [6, 7]. Non-operative management is still indicated in the highest-grade renal injuries since the success rates remain good albeit not as successful as observed in lower-grade injuries; thus, clinicians need to exercise vigilance when caring for patients with these injuries. Interest in salutary modalities such as renal artery embolization (RAE) has arisen as a means of improving the rate of renal salvage without the need for surgery and its intended risk of nephrectomy. The challenge lies in identifying which patient with renal trauma will benefit from RAE since it is not without risk and requires the mobilization of significant institutional resources. Several authors have retrospectively studied the MDCT findings in patients treated with RAE, but the prospective studies in this regard are lacking.

Retrospective Reviews

Fu et al. [8•] undertook a retrospective review of 26 patients who underwent angiography for predominantly grades III and IV renal injuries, 14 of whom underwent RAE at a major trauma center in Taiwan. Patients were taken for angiography if they had ICE on their initial MDCT and those undergoing RAE were noted to have significantly higher abbreviated injury scores and injury severity scores compared to those not embolized. The authors noted the critical importance of Gerota's fascia in tamponading renal hemorrhage and its relationship to RAE. 11 of 14 Patients (78.6 %) who had obvious disruption of Gerota's fascia ultimately required RAE, while 11 of 12 (91.7 %) did not, even though these patients had evidence of ICE on MDCT. On follow-up of at least 3 months or more, none of the embolized patients developed renal

Table 1 The original American Association for the Surgery of Trauma kidney organ injury scale proposed by Moore et al. [5]

AAST kidney organ injury scale 1989 [5]	
Grades[a]	Injury description
I	
Contusion	Microscopic or gross hematuria, urological studies normal
Hematoma	Subcapsular, non-expanding without parenchymal laceration
II	
Hematoma	Non-expanding perirenal hematoma confined to renal retroperitoneum
Laceration	<1.0 cm parenchymal depth of renal cortex without urinary extravasation
III	
Laceration	>1.0 cm parenchymal depth of renal cortex, without collecting system rupture or urinary extravasation
IV	
Laceration	Parenchymal laceration extending through the renal cortex, medulla, and collecting system
Vascular	Main renal artery or vein injury with contained hemorrhage
V	
Laceration	Completely shattered kidney
Vascular	Avulsion of renal hilum which devascularizes kidney

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[a] Increase by one grade if two or more separate injuries

failure or hypertension but the complication rate was 19.2 %. Two patients required repeat RAE for re-bleeding, two developed retroperitoneal abscesses, one of whom was embolized and one patient developed a minor renal infarct. The authors concluded that Gerota's fascia discontinuity, with its associated expanding perirenal hematoma, correlates with the need for RAE. It also stands to reason that there must be rupture of Gerota's fascia for a renal hematoma to significantly expand out of the retroperitoneum; thus, a very large perirenal hematoma is a marker of discontinuity of the fascia.

Charbit et al. [9•] performed a 5-year retrospective review of 58 patients with high-grade renal injuries at a regional trauma center in France and attempted to define the findings on MDCT that predicted the need for RAE. Patients were taken for angiography if they required more than 2 units of packed red blood cells and had a "large" perirenal hematoma or ICE. Focusing on disruption of Gerota's fascia, the authors concluded that while this finding had a 75 % positive predictive value and an 89 % negative predictive value of requiring RAE, it was significantly less predictive than what was found in the Taiwanese review. One explanation for these discordant results is that the timing of MDCT is critical since earlier scans may fail to detect disruption of Gerota's fascia, even though it is present. Although it is fairly strong, Gerota's fascia is extremely thin, of the order of 1 mm thick, which may make detection under normal circumstances very challenging. Another pertinent finding from Charbit's review was that the increasing size of a renal hematoma on MDCT, defined as the perirenal hematoma rim distance (PRD) or the maximal measure from the edge of the hematoma to the capsule of the kidney, correlated with the need for RAE. A PRD of 25 mm or more was associated with a sensitivity of 70 % and a specificity of 91 % for RAE. These data, although similar to finding of discontinuity of Gerota's fascia [8•], in and of itself are not accurate enough to reliably predict the need of RAE; however, the absence of ICE and a PRD of <25 mm had a 100 % negative predictive value for requiring RAE.

In a large retrospective review of patients with AAST grades III and IV renal injuries, Nuss et al. [10•] in Parkland, Texas, focused on two CT specific findings, ICE and perirenal hematoma, to identify those patients needing RAE. Similar to other studies [9•], the absence of ICE had a 100 % negative predictive value for requiring RAE but half of those with increasing hematoma size and ICE required RAE. Hematoma size was calculated through a series of four different measurements obtained from the MDCT scan including PRD, which when >40 mm predicted the need for RAE compared to smaller hematomas. The same group of authors published an additional retrospective review and increased their cohort from a 5-year review to a 9-year review at the same institution in Texas [11]. In this study they looked at PRD, ICE, and the complexity and location of the laceration in the kidney to create a renal trauma risk score (RTRS). Each was given 1 point for the presence of ICE, PRD >35 mm or a complex (medial) laceration which stratified patients into low risk (RTRS 0–1) and high risk (RTRS 2–3). Low-risk patients had a 7.1 % rate of requiring an intervention for bleeding compared to 66.7 % of the high-risk group. The subgroup of patients with all three radiographic findings had a 122-fold higher increase in the need for intervention for bleeding, but it must be noted that interventions in this study included nephrorrhaphy and nephrectomy in addition to RAE. From this study, it is apparent that complex lacerations with a medial component associated with ICE and a large perirenal hematoma have the highest rates of bleeding requiring an intervention.

Lin et al. in a retrospective review from China looked at subgroup analyses of patients with high-grade renal trauma undergoing arteriography which was performed in all patients with ICE or a transfusion of 4 units or more attributable to the kidney [12••]. RAE was then performed in patients who had ICE, pseudoaneurysm, and renal arteriovenous fistulae. While 35 patients had ICE and underwent angiography, only 22 (62.9 %) underwent RAE which is important to note since ICE alone is not a reliable enough finding to predict the need for RAE. Like other studies [10•], this study showed that the absence of ICE had an excellent negative predictive power since no patient out of the 46 without ICE required RAE, but it must be noted that in general about 7 % of patients without ICE may require RAE [9•, 11]. Likewise, increasing PRD was predictive of the need for RAE, and the average PRD in the group of patients undergoing RAE was 31.4 versus 13.5 mm in the group not requiring RAE. The authors noted that patients with perirenal hematomas limited to the vicinity of the kidney rarely required RAE, while those with large hematomas extending across to the vena cava or aorta for left and right hematomas, respectively, often required RAE as did those hematomas that extended down into the pelvis. From these findings, it can be inferred that the larger hematomas requiring RAE most likely had disruption of Gerota's fascia which supports the findings of the Taiwanese study [8•]. Similar to other studies [8•, 9•, 10•, 11], this study also demonstrated that the presence of ICE and an extensive perirenal hematoma was the most effective predictor for the need for RAE.

A recent study [13] pooled data from two Level 1 trauma centers in the state of Utah and applied the Parkland RTRS parameters: PRD, ICE, and location/complexity of the renal laceration, initially described by Dugi et al. [11] in their cohort. This study affirmed the findings of the Texas group by noting that the presence of ICE and a PRD

>35 mm was associated with 16.4- and 8.4-fold increased need for an intervention; however, these interventions were more often nephrectomy rather than RAE. In fact, RAE was rarely used to treat renal trauma by the Utah practitioner and only one patient out of eight requiring an intervention had RAE. The other dissimilar finding between the two groups was that the Utah authors found that a medial renal laceration was not an independent predictor of renal hemorrhage, while the Texas group did. The combination of a large perirenal hematoma and ICE on MDCT had the greatest correlation with the need for an intervention, a remarkably consistent finding of all reviews of blunt renal injury and RAE [8•, 9•, 10•, 11, 12••].

Conclusions

Most of the previously discussed studies were performed on AAST grades III and IV renal injuries and grades I and II injuries were typically excluded since these injuries have an exceedingly high rate of successful non-operative management [14]. Conversely, there is widespread consensus that renal pseudoaneurysms and renal arteriovenous fistulas have high failure rates of non-operative management and are firm indications for RAE [10•]. Patients with prolonged hematuria and advanced grade renal injuries may require angiography looking for a pseudoaneurysm and should undergo RAE if one is found. Significant confusion sets in when considering the management of AAST Grade V injuries and the role of RAE in patients with these injuries. Older literature suggests that there is no role for RAE in Grade V injuries which in the original OIS were described as a "completely shattered kidney" or an "avulsion of the renal hilum which devascularizes the kidney" [5]. Buckley and McAninch [15] proposed modifying the AAST renal injury scale to mirror changes in the management of high-grade renal injuries that evolved over the 25 years since the creation of the original OIS (Table 2). In their proposed revision, collecting system injuries are segregated and appear as grade IV or V injuries owing to their different management from that used for parenchymal or vascular injuries. Additionally, a shattered kidney would be considered a Grade IV injury rather than a Grade V one if it has signs of perfusion, suggesting that renal salvage via non-operative management is possible. Injuries to the collecting system are also reclassified as Grade IV injuries as are segmental renal artery injuries [16] but all lacerations, avulsions, and thromboses of the main renal vein or artery would be classified as Grade V injuries. In this new schema of the AAST kidney OIS, it is likely that only Grade IV and V injuries with ICE would require any intervention and most of the other lower-grade injuries and those without ICE could be managed expectantly.

Previously, Grade V renal injuries were considered a contraindication to non-operative management and prompt surgical intervention was considered the proper manage-

Table 2 The revised organ injury scale proposed by Buckley and McAninch which segregates collecting system injuries and reclassifies some of the previous AAST grade V injuries as Grade IV and segregates Grade V vascular injuries based on the presence or absence of thrombosis reproduced with permission

Revised kidney injury scale of Buckley and McAninch [15]	
Grades[a]	Injury description
I	
Parenchyma	Subcapsular hematoma and/or contusion
Collecting system	No injury
II	
Parenchyma	Laceration <1 cm in depth and into cortex, small hematoma contained within Gerota's fascia
Collecting system	No injury
III	
Parenchyma	Laceration 1 cm in depth and into medulla, hematoma contained within Gerota's fascia
Collecting system	No injury
IV	
Parenchyma	Laceration through the parenchyma into the urinary collecting system
	Vascular segmental vein or artery injury
Collecting system	Laceration, one or more into the collecting system with urinary extravasation
	Renal pelvis laceration and/or complete ureteral pelvic disruption
V	
Vascular	Main renal artery or vein laceration or avulsion main renal artery or vein thrombosis

[a] A renal unit can sustain more than one grade of injury and should be classified by the higher grade of the renal injury

ment in all cases of hemodynamic instability, even if this typically resulted in nephrectomy. A review of the role of angiography and RAE done in a group of patients with diverse mechanisms including trauma found that RAE failed in all the five patients with Grade V renal injuries [17]. Furthermore, two of the three deaths in this study occurred in patients with Grade V injuries who failed RAE but it must be stated that in this study RAE was done as a "last ditch" attempt to stop hemorrhage in a group of severely injured patients who underwent laparotomy first. Recently, Brewer and other urologists [18] in Knoxville, Tennessee, published a very different experience of nine hemodynamically unstable patients with relatively isolated Grade V renal injuries due to blunt trauma who were all successfully treated with RAE. A group of radiologists from Switzerland had three patients out of a series of nine who had successful RAE for Grade V renal injuries with no treatment failures or fatalities [19]. Curiously, the decision to perform angiography and RAE is somewhat dependent on the type of clinician caring for the patient as interventional radiologists tend to overuse RAE for lower-grade renal injuries and RAE in patients with penetrating trauma compared to urologists [20]. Urologists tend to over-rely on MDCT or "one shot" intravenous pyelograms before exploring patients with gunshot wounds to the abdomen with hemodynamic instability compared to trauma surgeons, but the surgeons are quicker to pull the RAE trigger for patients with moderate-grade renal injuries with associated ICE [21]. As a rule, hemodynamically unstable patients with high-grade renal injuries belong to the operating room rather than the angiography suite. In order to take these patients to angiography rather than the operating room, the personnel, resources, and intensive focused care typically found in the operating room must also be present in the angiography suite which is very uncommon among most trauma centers.

Obviously, Grade V renal injuries with thrombosis of the renal artery or vein are at much lower risk of hemorrhage when compared to those without thrombosis and ICE. In the former, non-operative management is indicated and often is successful, while in the latter attempted non-operative management will fail without RAE. Clinicians need to maintain a high state of vigilance following RAE since the failure rate of Grade V injuries with ICE following RAE is not insignificant. Similarly, clinicians should be wary of utilizing RAE to treat penetrating renal injuries since primary RAE for the management of these injuries has a 3-fold risk of failure compared to RAE for blunt injuries [14]. Fortunately, many of the treatment failures of initial RAE for penetrating trauma can be successfully managed with repeat RAE negating the need for nephrectomy [14].

The answer to the question "when should renal injuries undergo embolization?" is a complex one, but there are several important points to note in answering this question (Table 3). All hemodynamically stable patients with renal trauma warrant a trial of non-operative management. Low-grade renal injuries, AAST grades I–III, rarely if ever require embolization but grades IV and V injuries might require RAE if they are associated with ICE and a large perirenal hematoma. An obvious rupture of Gerota's fascia on MDCT with an associated large perirenal hematoma and ICE will typically require RAE but the ability to see discontinuity of Gerota's fascia is a challenge. Hematomas with a PRD of 35–40 mm or more that cross the midline or extend to the pelvis with signs of ICE will often require RAE, but smaller hematomas with ICE may be observed. Stable patients with prolonged hematuria in the setting of a high-grade renal injury may require angiography looking for a pseudoaneurysm to embolize, but this is a very infrequent scenario. Although there are limited data supporting the role of RAE in patients with high-grade renal injuries and hemodynamic instability, it must be stated that there needs to be a significant institutional commitment to make such management possible; otherwise this exposes the patient to undue risk. 70 Years ago, in a textbook reviewing the experience and lessons of emergency urological surgery from the Second World War, Swiersie stated, "one is never or hardly ever presented with a renal (trauma) condition that calls for immediate scalpel treatment" [22]. This statement is still true today and should be expanded to include angio-embolization of the kidney since very few renal injuries have the clinical presentation and MDCT findings to suggest that RAE is truly indicated.

Table 3 Some of the CT findings are strongly and moderately associated with the need for renal angio-embolization as well as lists the findings that suggest embolization will not be needed

CT scan findings predicting the need for renal angio-embolization
Strong predictors
• Intravenous contrast extravasation
• Pseudoaneurysm or arteriovenous fistula
• Massive perirenal hematoma crossing the midline or extending into the pelvis
• Rim of hematoma to capsule of kidney distance >40 mm
Moderate predictors
• Disruption of Gerota's fascia
• Complex laceration with medial (hilar) component
• Rim of hematoma to capsule of kidney distance 30–40 mm
Negative predictors
• Absence of intravenous contrast extravasation
• Perirenal hematoma contained within Gerota's fascia
• Rim of hematoma to capsule of kidney distance <30 mm
• Renal infarction or renal artery thrombosis

Compliance with Ethical Guidelines

Conflict of Interest Dr. Adams declares no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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