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Renal embolization for trauma: a narrative review

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Renal injuries commonly occur in association with blunt trauma, especially in the setting of motor vehicle accidents. Contrast-enhanced computed tomography is considered the gold-standard imaging modality to assess patients for renal injuries in the setting of blunt and penetrating trauma, and to help classify injuries based on the American Association for the Surgery of Trauma injury scoring scale. The management of renal trauma has evolved in the past several decades, with a notable shift towards a more conservative, nonoperative approach. Advancements in imaging and interventional radiological techniques have enabled diagnostic angiography with angiographic catheter-directed embolization to become a viable option, making it possible to avoid surgical interventions that pose an increased risk of nephrectomy. This review describes the current management of renal trauma, with an emphasis on renal artery embolization techniques.

Keywords: Kidney; Wound and injuries; Therapeutic embolization; Angiography

INTRODUCTION

The kidney is the most commonly injured solid organ in the genitourinary system and the third most commonly injured organ overall in trauma, following the spleen and liver [1–6]. Renal injuries have been reported in up to 5% of all trauma cases and have been identified in up to 10% of patients with abdominal trauma [3–10]. The relatively low prevalence of renal injuries in trauma can be attributed to its anatomical location; specifically, the kidneys are positioned in the retroperitoneum and held in place by the Gerota fascia. The organs are protected by perinephric fat and the psoas muscles, and are partially covered by the lower ribs and spinal column. This anatomical arrangement minimizes the risk of trauma to the kidneys; nonetheless, the kidneys are still prone to injury in the setting of blunt and penetrating traumas.

In the past several decades, the approach to managing renal trauma has undergone notable transformations, particularly in cases of blunt injury. There has been a shift from surgical to conservative or minimally invasive management, aligning with advances in cross-sectional imaging and the development of interventional radiological techniques [6–10]. This review article explores the current management of renal trauma, with an emphasis on the endovascular treatment of renal injuries.

ETIOLOGY AND EPIDEMIOLOGY

Renal injuries resulting from trauma are broadly categorized into two main types: blunt and penetrating injuries. While the distribution of these mechanisms may vary depending on the demographic served and location of a hospital, renal injuries are most often associated with blunt trauma, accounting for 80% to 90% of cases [4]. Penetrating renal trauma, although less common, may comprise up to 20% of renal trauma cases in certain urban areas

[6]. In adults, renal trauma predominantly affects young men, and the primary mechanism for blunt injuries is overwhelmingly attributed to motor vehicle accidents, followed by falls, sports-related incidents, and other less frequent causes [5,11]. Penetrating renal injuries most commonly result from gunshot wounds, followed by stab wounds [11]. Due to its protective anatomic location, isolated renal injuries are relatively infrequent, as shown by an 86% association rate with concomitant injuries in the setting of polytrauma [8,11]. Most cases of renal trauma are of lower-grade and non–life-threatening, and therefore are managed conservatively. Risk factors for high-grade renal trauma include female sex and medical comorbidities, such as peripheral vascular disease, renal insufficiency, and malignancy [10].

Iatrogenic renal injuries are not uncommon in certain practices and can be seen in the setting of percutaneous renal biopsies and partial nephrectomy in oncologic therapy for renal tumors. Although these procedures are associated with low rates of complications, renal hemorrhage is often a feared complication for which renal arteriography and renal artery embolization can be performed with a high success rate and preservation of kidney function [12–15].

CLASSIFICATION

In 1989, Moore et al. [16], as part of the Organ Injury Scaling Committee of the American Association for the Surgery of Trauma (AAST), devised a classification system for spleen, liver, and kidney injuries. This system was revised in 2018, incorporating multidetector computed tomography findings of vascular injuries to better assess organ injury severity and to provide a more standardized management approach [17]. The AAST injury scoring scales are the most widely accepted and used system of classifying traumatic injuries. This system utilizes a scale from 1 to 5, characterizing injuries based on anatomical descriptions that range from the least severe (1) to the most severe (5) [16]. The injury scoring scales play an important role in directing treatment strategies and assist in predicting the prognosis. This system also plays an essential role in effective communication with other physicians and healthcare professionals involved in the care of trauma patients.

There are five grades of injury in renal trauma as defined by AAST (Table 1) [18]. Grade I injury includes subcapsular hematoma or parenchymal contusion without laceration. Grade II injury includes perirenal hematoma confined to the Gerota fascia or laceration less than 1 cm in depth. Grade III injury includes renal parenchymal laceration greater than 1 cm in depth, any renal vascular injury, or active bleeding contained by the Gerota fascia. Grade IV injury includes renal parenchymal laceration extending into the urinary collecting system, renal pelvis laceration, segmental renal vein or artery injury, active bleeding beyond the Gerota fascia into the retroperitoneum or intraperitoneum, or renal infarct due to vessel thrombosis without active bleeding. Grade V injury includes laceration of the main renal artery or vein, a devascularized kidney with active bleeding, or a shattered kidney.

In a classification system devised by the World Society of Emergency Surgery (WSES), renal trauma is categorized into four grades. This system is largely based upon the AAST classification and the patient's hemodynamic status (Table 2) [19]. WSES grade I injury includes AAST grade I and II renal injuries. WSES grade II injury includes AAST grade III renal injuries or segmental vascular injuries. WSES grade III injury includes AAST grade IV and V renal injuries or any AAST grade with main vessel dissection or occlusion. WSES grade IV injury includes any renal injury with hemodynamic instability.

Table 1. AAST classification of renal injuries

AAST grade	Imaging finding
I	Subcapsular hematoma and/or parenchymal contusion without laceration
II	Perirenal hematoma confined to the Gerota fascia or laceration ≤1 cm in depth
III	Renal parenchymal laceration greater than >1 cm in depth, any renal vascular injury, or active bleeding contained by the Gerota fascia
IV	Renal parenchymal laceration extending into the urinary collecting system, renal pelvis laceration, segmental renal vein or artery injury, active bleeding beyond the Gerota fascia into the retroperitoneum or intraperitoneum, or renal infarct due to vessel thrombosis without active bleeding
V	Main renal artery or vein laceration, devascularized kidney with active bleeding, or shattered kidney

Advance one grade for bilateral injuries up to grade III.
AAST, American Association for the Surgery of Trauma.
Based on Kozar et al. [18].

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Table 2. WSES classification of renal injuries

Severity	WSES grade	AAST grade	Hemodynamic status
Minor	I	I–II	Stable
Moderate	II	III or segmental vascular injuries	Stable
Severe	III	IV–V or any grade parenchymal lesion with main vessels dissection/occlusion	Stable
Severe	IV	Any	Unstable

WSES, World Society of Emergency Surgery; AAST, American Association for the Surgery of Trauma.
Adapted from Coccolini et al. [19], available under the Creative Commons License.

CLINICAL AND DIAGNOSTIC ASSESSMENT

Initial assessment

The initial evaluation of a trauma patient includes maintaining and establishing a patent airway, ensuring adequate oxygenation and ventilation, and assessing the adequacy of circulation with hemorrhage control, which may be prioritized in certain situations [20]. When evaluating renal trauma, a comprehensive assessment follows with a detailed exploration of the patient's history and details of the injury if able. The mechanism of injury is important because there is a higher risk of renal injury in mechanisms involving acceleration-deceleration, and would prompt further imaging [21,22]. Additionally, the identification of preexisting renal abnormalities is essential, as even a low-velocity impact may increase the risk of renal injury [22,23]. In patients with a solitary kidney or a solitary functioning kidney, a nephrectomy should only be performed when deemed absolutely necessary.

On physical examination, certain signs may indicate renal trauma, including flank or upper abdominal hematoma, a palpable mass, ecchymosis, and rib fractures [22]. Macroscopic hematuria is not a reliable finding in renal trauma patients, as it may be absent in 50% of patients with grade II trauma and in up to 30% of patients with grade IV renal trauma [22,24]. For laboratory testing, obtaining a urine analysis to assess for microscopic hematuria, hematocrit to assess for blood loss, and creatinine to assess baseline renal function is recommended in addition to the usual trauma panel in patients presenting with renal injury. Imaging is warranted if there is a strong suspicion of renal injury based on the physical examination or associated injuries.

Imaging

Hemodynamically stable trauma patients often undergo series of examinations, including Focused Assessment with Sonography for Trauma (FAST). Despite its use to detect intraperitoneal bleeding, FAST has limited use in the evaluation of retroperitoneal hemorrhage. Contrast-enhanced ultrasound, although not widely used, has been suggested for hemodynamically stable patients with negative FAST findings and clinical suspicion for renal injury [19]. Contrast-enhanced computed tomography (CECT) is considered the gold-standard imaging modality for the assessment of hemodynamically stable patients presenting with renal injury in the setting of blunt and penetrating trauma [25]. CT is widely available and aids in determining the grade of renal injury, which, in turn, helps assess the appropriateness of nonoperative management for a stable patient.

Depending on the institution, the preferred imaging protocol for evaluating a suspected renal injury is a multiphase CECT with at least two phases: the arterial and portal venous phases. A postcontrast arterial phase of the abdomen and pelvis is obtained approximately 35 seconds following intravenous contrast injection. The resulting corticomedullary pattern of parenchymal enhancement allows the visualization of arterial injury, but is seldom sensitive for characterizing parenchymal or collecting system injury [17]. The portal venous phase is obtained 70 to 90 seconds after the intravenous contrast injection, resulting in a late corticomedullary or early nephrogenic phase in which there is optimal enhancement of the renal parenchyma, including the medulla. This phase is helpful for assessing solid organ injury and can help determine whether an arterial injury involves active extravasation or a pseudoaneurysm/arteriovenous fistula, as well as enabling the assessment of whether venous injury is present [17]. Additional phases include precontrast and delayed phase imaging, the latter of which is obtained 5 to 10 minutes following intravenous contrast injection. The precontrast phase may help identify acute bleeding or intraparenchymal hematoma, which may become isoattenuating in comparison to the normal renal parenchyma on postcontrast CT [26]. The delayed phase, also known as the excretory or urographic phase, allows optimal enhancement of the renal collecting systems, which may help visualize injury to the collecting system and ureteric injury [22]. Patients without concerning findings on CT, such as contrast extravasation, who are responsive to fluid therapy and blood transfusions, are admitted to the intensive care unit for conservative treatment.

RENAL TRAUMA MANAGEMENT

Operative management

Patients presenting with blunt or penetrating abdominal trauma require prompt assessment and intervention. Priorities for renal trauma management include preventing mortality by controlling hemorrhage, preserving nephrons, and averting complications [22]. Hemorrhage control is important for preventing hypothermia, coagulopathy, and acidosis [27]. While the management approach for traumatic renal injuries has shifted toward nonoperative strategies, it is important to recognize that life-threatening renal bleeding in hemodynamically unstable patients is an absolute indication for surgical exploration [22,28,29]. Hypovolemic shock patients unresponsive to fluid therapy and blood transfusions are immediately transported to the operating room after an initial basic examination. Emergency laparotomy is then performed, with the primary objective of hemorrhage control and salvaging the kidney if feasible. Fortunately, the majority of renal injuries are minor and are successfully managed by conservative treatment [30]. However, extensive kidney damage may be present in 20% to 40% of patients [30]. Therefore, surgery is indicated in only about 5% to 10% of patients and is generally reserved for hemodynamically unstable and select patients with high-grade renal trauma (grade IV and V) [27,31].

Urgent surgical exploration in the management of renal trauma frequently results in nephrectomy, but certain injuries— including small stab wounds to the renal parenchyma or injuries to the renal pelvis—can be closed primarily, while partial nephrectomy may be considered if adequate functional renal parenchyma can be preserved [25,32]. Nephrectomy is to be considered in cases where hemorrhage is attributable to the kidney, but identifying the kidney as the sole source of hemorrhagic shock can be difficult [8]. Currently accepted indications for surgery are avulsion of the renal pelvis, injuries to the vascular pedicle, and continued hemodynamic instability. Surgical options for renal vascular injury include gaining vascular control at the pedicle, followed by wedge resection, partial nephrectomy, and total nephrectomy [27].

Attempts are being made to avoid surgery when possible, as patients with renal trauma are at significant risk of nephrectomy, with rates reported as high as 64% for patients undergoing renal exploration [33]. The retroperitoneal location of the kidneys provides an innate tamponade mechanism to control excess bleeding and urinary extravasation [34]. Therefore, when the Gerota fascia is violated during renal exploration, the hematoma can no longer be contained, resulting in an increased risk of bleeding and nephrectomy. Furthermore, the repair of adjacent structures may be compromised due to uncontained urinary leakage [34].

Nonoperative management

The management of renal trauma traditionally involved surgical intervention as the primary approach. The rationale behind this practice was the concern for controlling bleeding, repairing damaged structures, and ensuring the preservation of renal function. However, over the years, there has been a shift in the management of renal trauma toward a more conservative, nonoperative, and organ-preserving approach [35]. Advances in diagnostic imaging have played a crucial role in the accurate assessment of renal injuries. This has enabled better risk stratification, leading to more tailored and less invasive management strategies. Nonoperative management can be categorized into conservative treatment or angiographic embolization. Conservative treatment is designed to stop hemorrhage caused by trauma through methods such as close observation, bed stabilization, fluid resuscitation, and blood transfusion. Diagnostic angiography with angiographic catheter-directed embolization has proven to be an effective treatment method with high technical and clinical success in appropriately selected patients [36].

For blunt trauma, the respective roles of expectant management, embolization, and surgery may depend on the grade of injury and overall patient status [15,37]. The standard of care for low-grade renal injuries, such as contusions, low-grade lacerations, and capsular hematomas, involves conservative nonoperative management, as these types of injuries are known to heal spontaneously with few complications [27]. The guidelines from the American Urological Association (AUA) and the European Urological Association (EUA) support initial conservative management for patients with lower-grade renal trauma (grades I–III) and even some hemodynamically stable higher grade injuries (grades IV–V). These guidelines aim to preserve renal function and avoid unnecessary interventions [35,38–43]. In two large-scale cohorts, nonoperative management was employed in 83.4% to 94.8% of renal trauma cases, with a failure rate ranging from 2.7% to 5.4%, showing its effectiveness in managing patients with renal injuries [11,44].

While nonoperative treatment is widely accepted as the standard for low-grade traumatic kidney injuries, the approach to high-grade traumatic kidney injuries remains a subject of debate, especially regarding patients who are hemodynamically unstable. Some authors have argued that prompt surgical intervention reduces complications, mortality, and the likelihood of late nephrectomy during follow-up. Conversely, more recent studies

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have reported successful nonoperative treatment for patients with high-grade blunt kidney injuries. Therefore, the success of nonoperative management in the context of high-grade renal injuries remains an unresolved issue [30,45,46]. A simplified algorithm for the management of patients with suspected renal injuries is shown in Fig. 1.

Several studies have described indications for angiographic embolization in high-grade renal injuries. Disruption of the Gerota fascia results in large, expansile retroperitoneal hematoma and indicates a need for renal angiography with embolization [8]. Perirenal hematoma thickness exceeding 35 to 40 mm also predicts a need for embolization [8,30]. A study by Ha et al. [30] noted that disruption of the Gerota fascia and hypotension were risk factors for the operative management of renal injuries. Active contrast extravasation on CT did not necessarily indicate a need for renal angiography and could be managed conservatively if the amount of extravasation is small and the patient is hemodynamically stable with mild symptoms. Elevated lactate levels were also not indicative of the need for operative management or renal angiography.

Among patients stabilized after high-grade renal injuries, routine reimaging utilizing CT was found to make little difference in management, as 12.5% of patients required intervention based on the repeated CT scan. Selectively reimaging patients with collecting system injuries increased the change in management to 23.1% [47]. Further research is needed to identify clinical factors capable of predicting changes in management after repeated imaging.

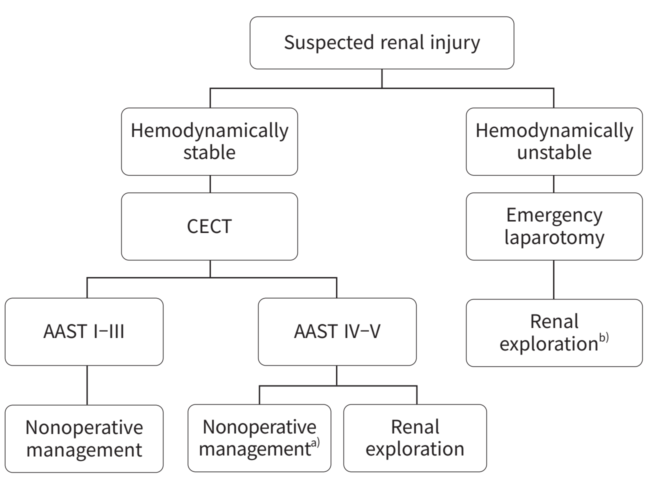

Fig. 1. Simplified algorithm for the management of patients with suspected renal injuries. CECT, contrast-enhanced computed tomography; AAST, American Association for the Surgery of Trauma. [a)]In select hemodynamically stable patients with grade IV and V renal injury, nonoperative management with close monitoring and serial CECT imaging may be an option. [b)]Renal exploration if hemorrhage is attributable to the kidney.

Management of penetrating renal trauma

CECT is the modality of choice for evaluating penetrating injuries of the abdomen and should be performed in all hemodynamically stable patients. On physical exam, entry and exit wounds must be assessed in all patients presenting with a penetrating injury. Although penetrating trauma is much less common than blunt injury, penetrating trauma is more likely to result in severe renal injury and is often associated with multiorgan injuries. In hemodynamically stable patients without expanding hematoma, renal salvage has shown to be possible despite multiorgan involvement in cases of penetrating renal trauma [48]. However, penetrating renal trauma does have a higher nephrectomy rate per grade of the injury, a higher rate of multiorgan injuries, and a higher failure rate of angioembolization than blunt renal trauma [48–50].

In the past, penetrating renal trauma was deemed an absolute indication for renal exploration. Currently, increasing evidence supports nonoperative management for hemodynamically stable patients with penetrating renal trauma, and there has been a notable shift towards endovascular repair, similar to what has been observed in the management of blunt renal trauma [51]. A high nonoperative success rate following penetrating trauma may be achievable, as demonstrated in a prospective study by Moolman et al. [52].

ENDOVASCULAR TECHNIQUES

Vascular access and catheters

In select patients for whom angioembolization is indicated, the procedures have been traditionally performed via femoral access. However, this approach is not without complications, including hemorrhage, pseudoaneurysm, arteriovenous fistula formation, and embolism [53]. Furthermore, there may be medical devices within the vicinity, such as pelvic binders, or placed in their femoral vessels as part of their resuscitation, potentially limiting access for endovascular interventions [54]. Although femoral access is the more common approach, radial access is recommended in certain situations, with benefits including improved quality of imaging, versatility for different cases in trauma settings, and improved post- procedure care. It is important to note that when performing renal artery angioembolization via a transradial approach, the left radial artery is generally preferred given the shorter distance, but a right radial approach may be more comfortable for the operator [55].

Under local anesthesia, vascular access is generally obtained via the common femoral artery with an 18- or 19-gauge puncture needle via a modified Seldinger puncture technique. An arterial sheath, ranging from 5F to 6F, is then carefully positioned in the common femoral artery, with the tip placed at the level of the external iliac artery. This positioning enables swift and secure exchange of angiographic catheters for aortography using a 5F Omni Flush (Angiodynamics) or pigtail catheter and selective catheterization of the main renal artery. Diagnostic digital abdominal aortography, typically at a rate of 15 to 20 mL/sec for a total of 30 to 40 mL of contrast, is then performed to identify any aberrant or accessory renal arteries or variants. This is followed by selective renal arteriography, which is directed to the injured kidney based on clinical, imaging, or surgical findings. In the latter case, surgical exploration may precede imaging, particularly in patients who are initially hemodynamically unstable, perhaps due to other intra-abdominal and pelvic injuries.

Angiographic selective catheterization of the renal artery is facilitated by the use of reverse-curve or double-curve catheters, such as Simmons (Merit Medical), SOS Omni (Angiodynamics), and Cobra (Merit Medical) catheters [27,56–58]. Several factors that may pose challenges to catheterization include atherosclerosis, narrowed or tortuous iliac arteries, renal artery stenosis, abdominal aortic aneurysm, or a mass effect from retroperitoneal tumors. Therefore, selecting a catheter that conforms to the vessel anatomy is advisable [59]. All catheter insertion and withdrawal steps are carefully executed over a 0.035-inch (0.09 cm) guidewire to prevent vessel dissection by the catheter tip. Manual contrast injections are performed using 8 to 10 mL of contrast medium, and the images are assessed for vascular pathology [58]. Multiple oblique projections may be needed to identify the take-off of renal arteries. Care must be taken in identifying accessory renal artery branches, as the failure to identify accessory branches may lead to missing active bleeding, resulting in inadequate embolization [56].

Microcatheters smaller than 2.8F can be used to select second- and third-order branches of the renal artery [57]. Superselective catheterization of renal artery branches involves the use of microcatheters either via coaxial or guidewire-controlled techniques, and allows the operator to be as selective as possible so that angioembolization is performed at or near the site of arterial injury. The use of microcatheter embolization in a superselective position significantly reduces the extent of renal infarction and promotes the preservation of renal function, while decreasing the risk of distal recanalization and rebleeding [60,61]. However, in an unstable patient where initial angiography demonstrates multiple areas of contrast extravasation, nonselective embolization may be the necessary option for expedited treatment [61].

Selection of embolic material

The choice of embolization materials for renal trauma is largely dictated by operator preference and the diameter of the target vessel [62]. Many embolic agents, including Gelfoam (Pfizer), polyvinyl alcohol (PVA), N-butyl-2-cyanoacrylate (NBCA), and microcoils, have been successfully used for renal artery embolization in the setting of trauma [63–68].

Gelatin foam, or Gelfoam, is a biodegradable embolic agent used for temporary embolization. It works by mechanically packing into a vessel lumen and promoting clot formation, leading to distal vessel obstruction and thrombus formation [69]. Gelfoam undergoes enzymatic degradation and is therefore avoided in the treatment of arteriovenous malformation because of its temporary embolic effect and risk of recanalization [59]. Given its particulate nature, Gelfoam should also be avoided when an arteriovenous fistula is present due to the risk of pulmonary embolism [70]. Interestingly, Gelfoam has been used in the setting of nonselective transcatheter complete renal embolization in a hemodynamically unstable patient with a grade V renal injury, resulting in vessel recanalization a few weeks post-procedure and enabling the partial preservation of renal function [71]. Although further research is needed to compare this technique with surgical nephrectomy in similar settings, such cases highlight the versatility of Gelfoam as an embolic agent.

PVA serves as a permanent occlusion agent and is commonly used to embolize small-caliber vessels. Its mechanism involves inducing an inflammatory response in the vessel wall, ultimately leading to angionecrosis [72]. While PVA is safe and effective for use in mechanical embolization of vessels, it has certain drawbacks. These include unpredictable embolization behavior and possible blockage of the delivery catheter, which are more commonly seen with noncalibrated particulates, given their heterogeneity in shape and lack of size precision. Calibrated PVA microspheres offer a controllable size distribution, enabling better localized targeted embolization [69,73].

NBCA, more commonly known as "glue," is a permanent liquid embolic agent that has been utilized since the 1980s but has had limited application compared to particulate agents and coils because of its difficulty of use and higher risk of complications due to its rapid and sometimes unpredictable polymerization [69,74]. An advantage of NBCA is that it can be effectively em-

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ployed in patients with systemic coagulopathy, as it readily precipitates upon contact with an ionic fluid medium (e.g., blood) and does not depend on the coagulation cascade [75]. The challenge lies in determining the optimal concentration of NBCA needed for targeted embolization, particularly in regions of high flow. Lipiodol (Guerbert) is mixed with NBCA to enhance radiopacity and increase the time it takes to polymerize [69]. Therefore, the composition of the NBCA and Lipiodol mixture determines the speed of polymerization and distance traveled in the target vessel. A high concentration of NBCA is used in high-flow regions and to achieve proximal rapid precipitation. A lower concentration of NBCA allows distal percolation, facilitating downstream embolization [75].

Coils serve as mechanical occlusion devices that are widely utilized in the embolization of bleeding vessels and aneurysms [69]. During embolization, the catheter is carefully positioned within the target vessel, and a delivery system is employed to push the coil through the catheter. The coil is strategically wedged against the vessel lumen or the aneurysm sac, effectively occluding the target primarily due to its mechanical occlusive and low thrombogenic properties [69]. The low thrombogenicity is attributed to the coil's capacity to mechanically impede blood flow initiating clot formation. This process is contingent on the body's ability to form blood clots, a factor that may vary across different areas of the coil, between coils, and among patients [69]. Bioactive coatings have been integrated into coils to enhance thrombogenicity. For example, fibered coils are particularly effective in increasing thrombogenicity, which is especially beneficial in patients with hemodynamic instability or hemorrhagic shock. Additional embolic agents such as Gelfoam may be used in conjunction with coils to efficiently occlude the lesion [76].

The main challenges in coil embolization include nontargeted embolization and coil migration. Nontargeted embolization typically results from coil misplacement or a mismatch between the coil and vessel size. Coil migration is typically seen with smaller coils, and although rare, there are reports of migration into the systemic circulation [69]. Extrusion into the parent vessel may be seen with large coils used to embolize aneurysms, which may lead to nontargeted thrombosis. Excessive radial force from an oversized coil can also cause elongation within the sac and potentially result in a ruptured aneurysm [69]. Other limitations are related to post-procedural imaging. These include beam hardening and scatter artifact limiting evaluation on CT, and susceptibility artifact limiting evaluation on magnetic resonance imaging [77]. Despite the challenges, the versatility provided by coils in terms of their size and shape makes them a popular embolic agent in the setting of renal trauma. Additionally, advances in delivery systems and accommodations for microcatheters have made it possible to place the coils in selective targets, increasing the rate of organ salvage and tissue preservation [78].

Success rates

The success rate of angioembolization for the treatment of renal injuries in the setting of blunt trauma ranges from 63% to 100%, with higher rates of failure following embolization observed in higher grade renal injuries [19,70]. In situations necessitating repeated embolization, the success rates parallel those observed in initial embolization, substantiating the justification for repeated interventions when clinically indicated [79]. A study by Hotaling et al. [50] showed that 78% and 83% of patients with grade IV and V injuries, respectively, avoided nephrectomy when treated with embolization, although the initial angioembolization success rate was low and most of the patients required some type of secondary intervention. Therefore, higher grade injuries were associated with an increased risk of initial angioembolization failure, but a repeated procedure has a high chance of preventing nephrectomy in these patients. Lastly, angioembolization results in similar or better renal function, lower complication rates, and a shorter length of stay in the intensive care unit, with equal transfusion requirements and rebleeding rates when compared to surgery [80,81].

Complications

While renal artery embolization is generally regarded as a safe procedure, there are potential complications including access site bleeding, renal infarction, iatrogenic vascular injury, postembolization syndrome, and renal abscess [27,66]. Postembolization syndrome, characterized by mild fever, flank pain, and leukocytosis, represents a recognized complication that can be effectively managed through conservative measures involving anti-inflammatory and analgesic medications [58]. Contrary to earlier findings reporting no correlation with acute kidney injury, a more recent study has identified acute kidney injury as a potential complication following renal artery embolization [82].

Follow-up

For patients with grade I and II renal injuries managed nonoperatively, follow-up imaging can be safely omitted. In cases of grade III to V renal injuries, the need for follow-up imaging is contingent upon the patient's clinical condition [19]. In patients with higher grade renal injuries (grade IV and V), repeated CECT with delayed excretory phase imaging is recommended within the initial 48 hours following admission, as urinary leaks are missed on initial imaging in 0.2% of all cases and in 1% of high-grade renal injuries [19].

CONCLUSIONS

Renal injuries most commonly occur in association with blunt trauma, and the primary mechanism for blunt injuries is overwhelmingly attributed to motor vehicle accidents. The AAST injury scoring scales are used to determine the severity, guide management, and assist in predicting the prognosis. Although the management of blunt trauma depends on the grade of injury and overall patient status, there is an increasing trend toward a more conservative, nonoperative approach. Additionally, guidelines from the AUA and EUA support the initial conservative management of lower-grade renal trauma in hemodynamically stable patients.

The indications for renal angiography with embolization include disruption of the Gerota fascia, resulting in a large, expansile retroperitoneal hematoma. Active extravascular contrast extravasation on CT is another radiological finding that may necessitate intervention. In appropriately selected patients for whom angioembolization is indicated, superselective embolization is typically recommended for preserving renal function. Various embolic agents are used for renal artery embolization, including temporary and permanent agents. The overall success rate of angioembolization in blunt renal trauma is high in lower-grade injuries, with a relatively low complication rate.

ARTICLE INFORMATION

Author contributions

Conceptualization: all authors; Investigation: all authors; Methodology: all authors; Project administration: all authors; Visualization: all authors; Writing–original draft: PL; Writing–review & editing: all authors. All authors read and approved the final manuscript.

Conflicts of interest

The authors have no conflicts of interest to declare.

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Data availability

Data sharing is not applicable as no new data were created or analyzed in this study.

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