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Case Report

Traumatic Kidney Injury: Intricacies Involved in Kidney Salvage

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Abstract

The kidneys, like the duodenum and the pancreas, are retroperitoneally located and this makes it hard to detect injury to them. The kidneys can be injured both by blunt and penetrating trauma. A high index of suspicion and mechanism of injury would help a clinician to diagnose injury to the kidneys. The injury is then confirmed by focused radiological examination. With the exclusion of exceptional cases, injury management involves non-operative management. This review briefly touches upon epidemiology, embryology, applied anatomy, physiology, pathophysiology, clinical, laboratory as well as radiological findings, therapy, and complications.

INTRODUCTION

Epidemiology

Trauma to the urogenital system encompasses 10% - 20% of all injuries with the involvement of the kidneys, despite its protected retroperitoneal location, in 60% to 90% of these instances. Such injuries are found predominantly in males, both among adults and children [1,2]. The mean age of involvement is between 31-38 years of age [3]. Renal injury constitutes 0.3% - 3.25% of all trauma victims [4]. The kidneys can be injured by either penetrating (1.4% - 3.3%) or blunt deceleration abdominal trauma, the latter accounting for most (90%) of the injuries [5]. Among adults, blunt renal trauma results predominantly from Motor Vehicle Accidents (MVA), assault, skiing accidents, and falls from height. Whereas in children blunt renal trauma results from falls [6], skiing, bicycle accidents, snowboarding, horse riding, and MVA. Blunt abdominal trauma in children is common in less than 5 years of age and often results in renal injury due to sparse perirenal fat, thin abdominal muscles, cartilaginous rib cage, fetal kidney lobulations, and relatively large kidneys [7]. Penetrating abdominal trauma is common in children over 14 years of age. It is important to remember that there may be concurrent injury to other organs, especially following penetrating abdominal trauma.

EMBRYOLOGY AN APPLIED ANATOMY

Embryology

The urogenital ridge develops as an elongated mass from embryonic folding during the fourth week of embryonic development. Between the 6th and 10th week of the life of the embryo, twenty nephrons, capable of secreting urine, are formed. The metanephric kidney that appears around the fifth week of embryonic life develops into the permanent kidney. Giant-Cell Derived Neurotrophic Factor (GDNF) induces the formation of ureteric bud from the mesonephric duct. By the 6th week, the ureteric bud begins to branch. The first bifurcation forms the renal pelvis and caudal as well as the cranial lobes of the kidney. The next four bifurcations form major calyces and the following four form minor calyces. Gdnf induces the branching process. The branching process continues up to 32 weeks of embryonic development forming 1-2 million collecting tubules. The tip of each collecting tubule induces the blastemal caps to form nephric vesicles, resulting in the formation of functioning nephrons which develop further into nephric tubules consisting of Bowman's capsule, proximal and distal tubules, and the loop of Henlee. VEGF2 secreted by the podocyte precursor lining the Bowman's capsule draws endothelial cells to form early vascular tufts resulting in the formation of afferent and efferent arterioles of the glomerulus. Earlier on, both the kidneys are close together in the sacral region of the embryo. Between 6th to 9th week of embryonal development they are drawn apart and ascend to their final position in the lumbar area [8].

Applied anatomy

The kidneys rest on either side of the spinal column by the bodies of 12th thoracic vertebra to 3rd lumbar vertebra in such a way that the medial border is rotated somewhat anteriorly and lateral border posteriorly. Each adult kidney measures 11 cm. (centimeter) long, 6 cm. wide, 3 cm. thick with the right kidney ½ cm shorter than the left. The anterior surface of each kidney is round, convex whereas the posterior surface is flatter and is encased in four layers of coverings consisting of from inside out, true capsule, perirenal fat, renal facia, and retroperitoneal or pararenal fat. Each kidney contains 4-28 lobes, and each lobe comprises of a central medulla encompassing loops of Henlee and collecting ducts surrounded by the cortex embracing glomeruli, proximal, and distal tubules.

Vascular supply, lymphatic drainage, and innervation:

The rental artery arising from the aorta supplies arterial blood to the kidneys with the right renal artery at a lower level than the left. The longer right renal artery passes behind the inferior vena cava, the renal vein, the head of the pancreas, and the second part of the duodenum. The shorter left renal artery passes behind the left renal vein and the body of the pancreas. Each renal artery divides into anterior and posterior branches before dividing into five segmental arteries.

Unlike the renal artery, there are no segmental arrangements for the renal veins. The capillaries draining the medulla and the cortex join successively to form the renal vein draining into the inferior vena cava. The left renal vein is longer than the right and crosses over the aorta.

The lymphatics of the kidney drain into the lymph nodes around the aorta and the inferior vena cava.

Innervation of the kidney is from the renal plexus, which is supplied by the dorsal roots of T11, T12, celiac axis containing sympathetic fibers, the semilunar ganglion, the splanchnic, and the vagus nerve (parasympathetic) [9].

Renal physiology

The kidney's functions include preserving fluid, preserving electrolytes including sodium, potassium, and others; acid-base balance, controlling the absorption of glucose, amino acid, and other small molecules; removing toxins; controlling blood pressure; producing erythropoietin; and the activation of vitamin D. Renal corpuscles consist of many millions of filtration units each comprising of a glomerulus and a Bowman's capsule that carry out purification functions. Urine is generated via glomerular filtration which ranges from 120 to 125 milliliters per minute. Glomerular filtration is facilitated by a glomerular capillary hydrostatic pressure of 55 millimeters of mercury (mm of Hg) and an osmotic pressure in the capsular space that is 0 due to the absence of proteins. The renin-angiotensin system, the sympathetic system, and catecholamines play a role in maintaining the Glomerular Filtration Rate (GFR). The tubular system of the kidneys plays a role in its absorptive and secretory functions via the proximal convoluted tubule, the ascending and descending limbs of loop of Henlee, and the distal convoluted tubule [10].

Pathophysiology

The mechanism of blunt trauma results from acceleration and deceleration influences, causing injury to the renal parenchyma and vascular injury as well as rupture and thrombosis, respectively. Kidney abnormalities exacerbate the effects of an injury to the kidney. Penetrating trauma to the kidney is inflicted either by gunshots in many individuals or stab wounds in a minority of individuals [11]. The kidney's endocrine function includes the secretion of hormones such as Renin-Angiotensin (RA), erythropoietin, vitamin D3; the production of the enzyme Kallikrein; and the production of local hormones such as prostaglandins, endothelin, and adrenomedullin. Hormones such as aldosterone, angiotensin, and natriuretic peptides influence the kidney's function. Although renal trauma per se does not lead to a change in hormonal homeostasis, severe abdominal trauma involving the kidneys along with injury to other intraabdominal organs may lead to hormonal imbalance. Hypovolemia immediately following trauma leads to vasoconstriction with diversion of blood flow to the brain and the heart at the expense of abdominal organs and the kidneys. This is due to the activation of the sympathetic nervous system via catecholamines secreted by the adrenal medulla resulting in the conservation of fluid through pressure-sensitive baroreceptors which are found in renal arteries and resulting in the secretion of Adrenocorti Cotrophic Hormone (ACTH), Growth Hormone (GH), and vasopressin ensuing conservation of water and salt, leading to the restoration of intravascular volume [12].

Clinical findings

In a hemodynamically stable patient, a detailed history of occurrences leading to the injury helps to unravel the mechanism of injury which, in turn, helps to execute a treatment plan. In an unstable patient, initial evaluation involves the ABCs i.e., airway, breathing, and circulation, following which action is undertaken to stabilize an unstable patient. The presence of any underlying renal anomaly leads to significant trauma to the kidney following even a minor injury, entailing further urological investigation [13].

Blunt injury to the lower back, upper abdomen, and flank involves the kidney. Penetrating injury consists of an entry and an exit wound that must be examined carefully. The presence of discoloration of the skin such as ecchymoses, rib fracture, hematoma, tenderness over the kidneys, and the presence of visible hematuria indicates renal trauma [14].

Laboratory examination

Urine analysis for hematuria, hematocrit for significant blood loss, and creatinine for renal function evaluation is initiated. Macroscopic hematuria is present in about half of the patients following kidney injury [15] and microscopic hematuria is defined as when greater than 3 Red Blood Cells (RBCs) per (/) Higher Power Field (HPF) in adults and greater than 50 RBCs/HPF in children is seen upon urine analysis. Microhematuria defined as <50 RBCs/HPF in children is common due to the anatomy of

Table 1: AAST classification of renal trauma.

Injury Grade*	Injury Type	Narrative	Therapy
I (22%-28%) #	Contusion	Microscopic or gross hematuria, urologic studies normal	Non-operative in blunt injury [26].
	Hematuria	Subcapsular, nonexpanding without parenchymal laceration	
II (28%-30%) #	Hematoma	Nonexpanding perirenal hematoma confirmed to renal retroperitoneum	Non-operative in blunt injury [26].
	Laceration	<1.0 cm parenchymal depth of renal cortex without urinary extravasation	
III (20%-26%) #	Laceration	>1.0 cm parenchymal depth of renal cortex without collecting system rupture or urinary extravasation	Non-operative with angioembolization when indicated [26].
IV (15%-19%) #	Laceration	Parenchymal laceration extending through renal cortex, medulla, and collecting system	Non-operative in hemodynamically stable patients [16].
	Vascular	Main renal artery or vein injury with contained hemorrhage	
V (6%-7%) #	Laceration	Completely shattered kidney	Non-operative in hemodynamically stable patients [16].
	Vascular	Avulsion of renal hilum which devascularizes kidney	

*Advance one grade for bilateral injuries up to grade III [6].

the kidney and the presence of undiagnosed renal disease. There is no clear distinction between the degree of hematuria and the extent of renal injury. Injury to the other organs is evaluated by a complete blood count, glucose, electrolytes, blood gases, liver function test, lipase, and amylase.

Radiological diagnosis

Indication: The aim of radiological examination is to grade injury to the kidney, evaluate the other kidney, demonstrate underlying renal anomaly, and injury to other organs. Computerized Tomography (CT) scan is undertaken in those who are hemodynamically stable where there is injury (blunt and penetrating) to the upper abdomen and the lower thorax, hematuria, lower rib fracture, and/or ecchymoses over the flank [16]. In the pediatric population, generally, imaging is carried out when blunt abdominal trauma is accompanied with a greater than 50 RBCs/HPF on microscopic examination of the urine. Children with minimal symptoms and signs, i.e. less than 50 RBCs/HPF on urine analysis, can initially undergo clinical examination, blood tests, Ultrasound (US), Contrast-Enhanced US (CEUS), and Eco-doppler, [17]. CT in the pediatric age group is indicated in hemodynamically stable or stabilized patients following penetrating injury or in those with suspected abdominal trauma, independent of the grade of hematuria.

Re-imaging is undertaken in those with suspected complications following renal injury and with clinical deterioration [16].

Imaging of choice

CT scan: Contrast Enhanced CT (CECT) with contrast administration via an intravenous route is the preferred method of imaging in both penetrating and blunt renal trauma [16]. It provides, without the fear of contrast enhanced toxicity, functional information on the kidneys in addition to information on any injury to other organs as well as the anatomical location of the injury to the kidneys for staging reasons. Different phases of contrast enhanced images are taken that include a pre-contrast renal phase, a post-contrast vascular phase, and delayed pictures to visualize the excretory system. CT helps to identify those patients with a high-risk criterion for Non-Operative Management (NOM) failure.

Other radiological tests

Intravenous Pyelography (IVP): IVP is used intra-operatively in those who were unable to undergo CECT because of hemodynamic instability. It helps to delineate the status of the uninjured kidney.

The US is useful in pediatric patients due to the absence of any radiation effects. Although the US can identify laceration and hematoma affecting the kidneys, it cannot differentiate extravasated urine from blood as well as injury to the renal pedicle and renal segmental infarct. However, the US is useful for postoperative follow up examination of the kidneys to detect any suspected complications. CEUS is used in pregnant women and in children to diagnose pseudoaneurysm, thrombosis, post-traumatic arteriovenous fistulae, and urinary extravasation [18]. It also increases the accuracy of Extended Focused Assessment with Sonography in Trauma (E-FAST) by greater than 80%. Although E-FAST, US, and Doppler US are useful in trauma, they underestimate injuries by up to 30%. CEUS is not indicated in cases of suspected injury to the urinary tract and collecting system. Instead CECT with late urography phase is suggested.

Contrast radiography

Intravenous Urography (IVU) is used in renal trauma discovered during surgery in unstable patients before exploring the retroperitoneal hematoma. Excretory urethrography is used in perineal injuries as well as in suspected ureteral and bladder injuries [19].

Magnet Resonance Imaging (MRI)

MRI is used to diagnose renal injury in fertile and pregnant women, in children and those with allergy to iodine, in those with equivocal CT, and in the follow up stage of urinary tract trauma [20].

Therapy

The important components of management of renal trauma includes control of hemorrhage, renal sparing, and the prevention of complications.

The American Association for the Surgery of Trauma (AAST) classification of renal trauma is shown in the following table 1 [21]. Non-Operative Management (NOM) is favored in all five grades, provided there is hemodynamic stability in the affected individuals. It is also important that, during non-operative management, close observation of the patient with monitoring of vital signs, supportive care, laboratory monitoring, reimaging following any clinical setback, and the use of angioembolization are ensured. NOM results in a greater kidney preservation rate, a shorter hospital stay, and equal complication rate to Operative Management (OM). Even in penetrating trauma, non-operative management is successful in most [22]. Operative management is indicated in hemodynamically unstable patients who are not responsive to resuscitative efforts, patients with renal salvage [23] as well as those with peritonitis, failed embolization, persistent blood loss, and pulsatile blood clot.

The prevention of renal injury following severe blunt abdominal injury that includes kidney trauma consists of monitoring urine output and renal function tests including serum creatinine, intravascular expansion with balanced salt solution such as lactated ringers, maintaining renal perfusion pressure after appropriate volume expansion using vasopressors such as norepinephrine, angiotensin II in those who have angiotensin II deficiency, avoiding nephrotoxic agents including radiocontrast agents if possible, avoiding hyperglycemia and using insulin infusion when appropriate. Initiation of appropriate treatment of renal failure when detected [24].

Complications

Primary complications include hypertension, bleeding, infection, sepsis, abscess, urinary fistula, extravasation of urine, and urinoma. Secondary complications that are seen later consist of bleeding, hypertension, hydronephrosis, renal stones, pyelonephritis, arteriovenous fistula, and pseudoaneurysm [25].

CONCLUSION

Although complex, the diagnosis and management of the kidney injury can be made by having a high degree of suspicion from mechanism of injury and appropriate radiological procedure. The management principles involve hemodynamic stabilization, kidney salvage, and avoiding complications.

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REFERENCES

1. Veeratterapillay R, Fuge O, Haslam P, Harding C, Thorpe A. Renal trauma. J Clin Urol. 2017; 10: 379–390.
2. Grimsby GM, Voelzke B, Hotaling J, Sorensen MD, Koyle M, Jacobs MA. Demographics of pediatric renal trauma. J Urol. 2014; 192: 1498–1502.
3. Kansas BT, Eddy MJ, Mydlo JH, Uzzo RG. Incidence and management of penetrating renal trauma in patients with multiorgan injury: Extended experience at an inner-city trauma center. J Urol. 2004; 172: 1355–1360.
4. McClung CD, Hotaling JM, Wang J, Wessells H, Voelzke BB. Contemporary trends in the immediate surgical management of renal trauma using a national database. J Trauma Acute Care Surg. 2013; 75: 602–606.
5. Hotaling JM, Sorensen MD, Smith TG 3rd, Rivara FP, Wessells H, Voelzke BB. Analysis of diagnostic angiography and angioembolization in the acute management of renal trauma using a national data set. J Urol. 2011; 185: 1316–1320.
6. Voelzke BB, Leddy L. The epidemiology of renal trauma. Transl Androl Urol. 2014; 3:143–149.
7. Lambert SM. Pediatric urological emergencies. Pediatr Clin N Am. 2012; 59: 965–976.
8. Rehman S, Ahmed D. Embryology, Kidney, Bladder, Ureter. StatPearls. Treasure Island (FL): StatPearls Publishing; 2023.
9. Keith W, Kaye KW, Marvin E, Goldberg ME. Applied anatomy of the kidney and ureter. Urologic Clinics of North America. 1982; 9: 1-13.
10. Zyan A. Renal physiology. J. Interven. Nephro. 2022; 5: 66–69.
11. Kansas BT, Eddy MJ, Mydlo JH, Uzzo RG. Incidence and management of penetrating renal trauma in patients with multiorgan injury: extended experience at an inner-city trauma center. J Urol. 2004; 172: 1355–1360.
12. Bajwa SJ, Kulshrestha A. Renal endocrine manifestations during polytrauma: A cause of concern for the anesthesiologist. Indian J Endocrinol Metab. 2012; 16: 252-257.
13. Schmidlin FR, Schmid P, Kurtyka T, Iselin CE, Graber P. Force transmission and stress distribution in a computer-simulated model of the kidney: an analysis of the injury mechanisms in renal trauma. J Trauma. 1996; 40: 791–796.
14. Buckley JC, McAninch JW. The diagnosis, management, and outcomes of pediatric renal injuries. Urol Clin North Am. 2006; 33: 33–40.
15. Aragona F, Pepe P, Patane D, Malfa P, D'Arrigo L, Pennisi M. Management of severe blunt renal trauma in adult patients: A 10-year retrospective review from an emergency hospital. BJU Int. 2012; 110: 744–748.
16. Morey AF, Brandes S, Dugi DD 3rd, Armstrong JA, Breyer BN, Broghammer JA, et al. Urotrauma: AUA guideline. J Urol. 2014; 192: 327–335.
17. Fernández-Ibieta M. Renal Trauma in Pediatrics: A Current Review. Urology. 2018; 113: 171- 178.
18. Miele V, Piccolo CL, Galluzzo M, Ianniello S, Sessa B, Trinci M. Contrast-enhanced Ultrasound (CEUS) in blunt abdominal trauma. Br J Radiol. 2016; 89: 20150823.
19. Cabrera Castillo PM, Martínez-Piñeiro L, Maestro MÁ, De la Peña JJ. Evaluation and treatment of kidney penetrating wounds. Ann Urol (Paris). 2006; 40: 297–308.
20. Leppäniemi AK, Kivisaari AO, Haapiainen RK, Lehtonen TA. Role of magnetic resonance imaging in blunt renal parenchymal trauma. Br J Urol. 1991; 68: 355–360.
21. Moore EE, Shackford SR, Pachter HL, McAninch JW, Browner BD, Champion HR, et al. Organ injury scaling: spleen, liver, and kidney. J Trauma. 1989; 29:1664–1666.
22. Keihani S, Xu Y, Presson AP, Hotaling JM, Nirula R, Piotrowski J, 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: 418–425.
23. Morey AF, McAninch JW, Tiller BK, Duckett CP, Carroll PR. Single shot intraoperative excretory urography for the immediate evaluation of renal trauma. J Urol. 1999; 161: 1088–1092.

24. Kellum JA, Romagnani P, Ashuntantang G, Ronco C, Zarbock A, Anders HJ. Acute kidney injury. Nat Rev Dis Primers. 2012; 7: 52.

25. 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: 195–200.

26. Erlich T, Kitrey ND. Renal trauma: The current best practice. Ther Adv Urol. 2018; 10: 295-303.