CHAPTER 2

RENAL INJURIES: PENETRATING AND BLUNT

GU Tract Structure	Ch 2 Kidney	Ch 3 Ureter	Ch 4,5 Bladder	Ch 6,7,8,11 Urethra	Ch 8,9 Scrotum Testis	Ch 8,9 Spermatic Cord	Ch 8,10 Penis
No. Patients With Injury to Structure	132	36	72	83	199	14	128
% of Total GU Injuries	19.1	5.2	10.4	12.0	32.8	2.0	18.5

GU: genitourinary

INTRODUCTION

Data from 17,726 battle casualties admitted to all the US Army hospitals in the Republic of Vietnam (RVN) from March 1966 to July 1967 (60% of all patients wounded during this time) revealed that 13.8% of all wounds involved the abdomen, and that the kidney was involved in approximately 9% of those with abdominal wounds.[1] The mortality in this group (who had renal wounds as a component of their abdominal wounds) was 7.8% during the Vietnam War, compared with a mortality of 25% during the Korean War and 35% for such wounds during World War II.[1] As reported[2,3] by urologists, the incidence of wounds and injuries of the genitourinary tract among total casualties treated at 3 hospitals in Vietnam was between 3% and 4.2%; renal wounds and injuries accounted for 31% to 35% of the total number of urological wounds treated.Working in hospitals in Japan, primarily at the US Army Hospital Camp Zama, from February 1966 through March 1971, we authors (JNW and JWW) managed 692 genitourinary wounds and injuries in 503 patients. Renal trauma occurred in 132 (26.2%) of 503 patients with urological injuries and accounted for 132 (19.2%) of 692 of all genitourinary wounds and injuries (Table 2-1 and Figure 2-1).

CAUSES AND MECHANISMS OF INJURY

Renal injuries are generally classified into 2 broad groups depending on whether the cause of the trauma was a penetrating or a bluntforce. The approach to the evaluation and management can be quite different for penetrating (ie, *wounds*) as opposed to closed (ie, *blunt*) renal injuries. In the civilian sector, blunt injuries account for 80% to 90% of renal trauma, and wounds (also called penetrating

TABLE 2-1
GENITOURINARY TRACT INJURIES* FEBRUARY 1966–MARCH 1971

Injured GU Tract	Patients With Injured Organ		Injuries to GU Organs	
	No.†	%‡	No.	%
Scrotum-Testis	199	39.6	227	32.8
Kidney	132	26.2	132	19.1
Penis	128	25.4	128	18.5
Urethra	83	16.5	83	12.0
Bladder	72	14.3	72	10.4
Ureter	36	7.2	36	5.2
Spermatic Cord	14	2.8	14	2.0
Totals:			**692**	**100.0**

*In 503 patients seen by the authors during the Vietnam War at US Army Hospital, Camp Zama, Japan
†Some patients had injuries to more than one GU tract organ; the total number of patients (503) is less than the number of injuries
‡Number of patients with injured organ / 503 patients (x 100) = %
GU: genitourinary

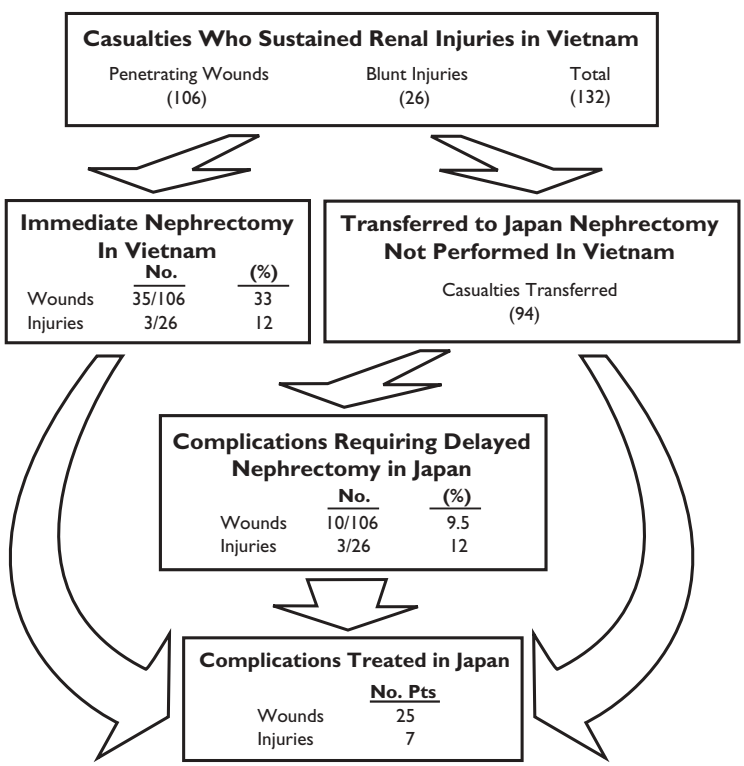

Fig. 2-1. Casualty flow chart.

trauma), 10% to 20%. These figures are reversed in wartime renal trauma. Of the 132 renal injuries we managed in Japan, 106 (80%) were secondary to penetrating missiles, and 26 (20%) of 132 from blunt trauma (Table 2-2).

TABLE 2-2
CATEGORY OF RENAL INJURIES

Category	Patients No.	Patients %
Penetrating	106	80.3
Blunt	26	19.7
Total Injuries:	**132**	**100.0**

Closed blunt renal injuries resulted from vehicular accidents, direct blows, falls from heights, and blast injuries similar to the experience in the civilian sector. Rapid deceleration can cause damage to the renal pedicle, and multiple organ injuries are more likely from high-velocity impact trauma.

The wounds were caused by high-velocity missiles—not only bullets but also fragments from explosions of nearby mortars and mines—as well as more-distant, lower-velocity fragments. In assessing penetrating renal and other organ injuries, ballistics and weapon characteristics are important. Bullet velocity has the greatest effect on soft-tissue injuries:

$$KE = \text{mass} \times V^2 \div 2$$

where *KE* represents kinetic energy, *mass* is taken as equal to the missile's weight, and *V* represents velocity. The higher the velocity of the missile, the greater the kinetic energy and the greater the potential for energy transfer to the target. The greater the energy transfer, the larger the temporary cavitation in the body, which increases the extent of soft-tissue stretch and destruction.[4] (Ballistic wounds, wound ballistics, and wounding characteristics of some weapons are discussed more extensively in *Conventional Warfare: Ballistic, Blast, and Burn Injuries*, an early volume in the *Textbooks of Military Medicine* series.[5])

The muzzle velocity of a high-velocity missile has been defined as being greater than 2,000 ft/s.[6] In Vietnam, many of the wounds were caused by high-velocity missiles. As in other areas of the body, the amount of organ damage sustained depended on the amount of energy absorbed from the missile and from the type and location of the wound or wounds. These wounds of the kidney are associated with a high incidence (80%–90%) of other intraabdominal organ injuries that require operative treatment.[1,6–8] In decreasing order of frequency, the most commonly injured viscera are the liver, colon, spleen, small bowel, pancreas, and the great vessels.[1,6–8] Ninety-seven (92%) of our 106 patients with wounds of the kidney had injuries to other organ systems, often life-threatening ones, which dictated the priorities of care.

CLASSIFICATION AND STAGING

In Vietnam, the renal damage from wounds caused by penetrating missiles varied from simple contusions and superficial lacerations (minor injuries) to deep lacerations, often extending into the collecting system, and cavitations

with extensive necrosis and shattering renal parenchyma including total ablation of the renal unit and major renal vascular damage (major, severe, or critical injuries). The majority of these high-velocity renal wounds can be categorized as high grade, major, and often critical and life-threatening requiring immediate surgery. In Vietnam, the bulk of definitive staging of renal wounds was accomplished by surgical exploration and operative assessment. Renal imaging was primarily accomplished by either intraoperative or high-dose infusion pyelography, which may have defined the side of injury (often apparent prior to the study) and confirmed the probability of a "normal" opposite kidney.

Accurate staging of renal injuries would not be relevant if all renal trauma cases were explored. However, in the nonwartime battlefield environment since the introduction of contrast-enhanced computed tomography (CT, then known as computerized axial tomography) and demonstration of its superior utility in defining and grading injury,[9] most blunt injuries and a significant number of gunshot wounds (GSWs) are treated nonoperatively in major civilian trauma centers.[10,11] Before contrast CT was available, intravenous pyelography (IVP), tomography, and renal angiography were used to define and stage the extent of injury leading to numerous classifications of renal trauma. In 1989, the American Association for Surgery of Trauma's (AAST's) Organ Injury Scaling Committee published the most current and widely used classification system for renal injuries (Table 2-3 and Figure 2-2).[12] In this system, the grade of renal injury relates to the degree of injury (defined primarily by CT) and serves as a reliable guideline for management; that is, grades I and II injuries are minor, generally uncomplicated, and require no surgery; whereas grades III, IV, and V injuries are considered major with increasing likelihood of complications and surgery. Contrast CT can often define other asso-

TABLE 2-3
CLASSIFICATION OF RENAL INJURIES

Grade*	Type	Injury Description†
I	Contusion	Microscopic or gross hematuria, normal urological studies
	Hematoma	Subcapsular, nonexpanding without parenchymal laceration
II	Hematoma	Nonexpanding perirenal hematoma confined to renal retroperitoneum
	Laceration	< 1 cm depth of parenchymal cortex without urinary extravasation
III	Laceration	> 1 cm parenchymal depth renal cortex without either rupture of collecting system or urinary extravasation
IV	Laceration	Parenchymal laceration through renal cortex, medulla, and collecting system
	Vascular	Injury to main renal artery or vein with contained hemorrhage
V	Laceration	Completely shattered kidney
	Vascular	Avulsion of the renal hilum, devascularizing the kidney

*For bilateral injuries, advance one grade up to grade III

†Based on most accurate assessment at autopsy, laparotomy, or radiological study

Adapted with permission from Moore EE, Shackford SR, Pachter HL, et al. Organ injury scaling: Spleen, liver, and kidney. *J Trauma*. 1989;29(12):1665–1666.

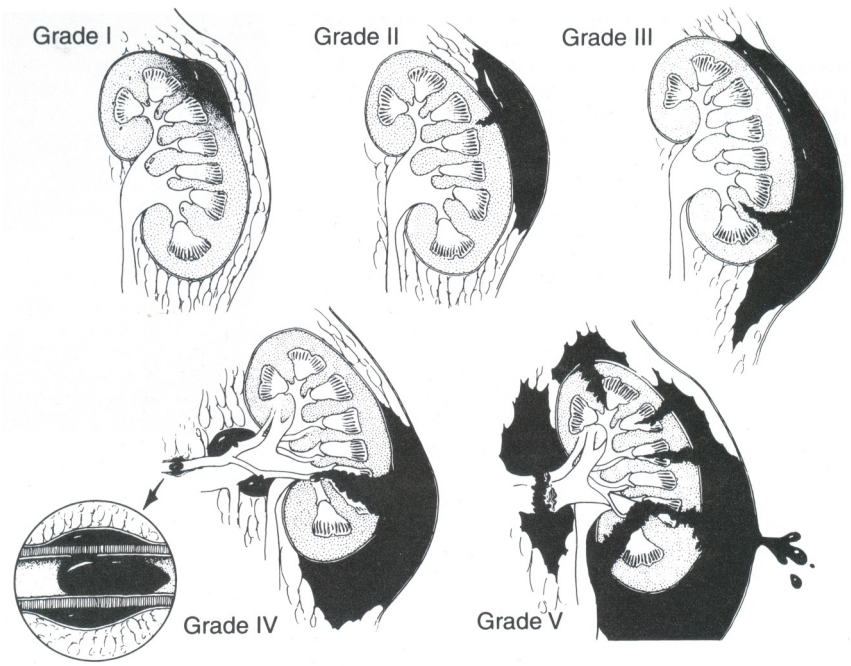

Fig. 2-2. Classification of renal injuries by grade. Classification based on the Organ Injury Scale, American Association for the Surgery of Trauma. Reproduced with permission from McAninch JW, Santucci RA. Genitourinary trauma. In: Walsh PC, Retik AB, Baughan ED Jr, Wein AJ, eds. *Campbell's Urology*. Vol 4. 8th ed. Philadelphia, Pa: Saunders: 2002: 3709.

ciated intraabdominal organ injury (eg, liver, spleen, bowel, pancreas). Infusion or high-dose excretory urography is significantly less sensitive and specific but its use is not obsolete in either the battle zone or the civilian trauma setting when (*a*) preoperative evaluation is not possible and (*b*) there is intraoperative evidence of undefined renal injury from both blunt and penetrating trauma.[13]

HEMATURIA

The presence of *hematuria* (ie, > 5 red blood cells per high-power field on a microscopic examination, a positive dipstick, or gross blood in the urine) is highly predictive of traumatic renal injury. However, the absence and degree of hematuria may not reliably predict the grade of renal injury. Hematuria is absent in up to 36% of blunt renal vascular injuries[14]; in 1 series of 181 traumatic wounds and injuries, the urinalysis was normal in 41 (29%) patients, including 10 with major parenchymal wounds.[8] Although gross hematuria is usually associated with significant renal parenchymal injury, it can be seen from contusions. Microhematuria can be seen in 42% of major and 76% of minor renal wounds.[14] Moreover, microhematuria associated with shock (systolic blood pressure < 90 mm Hg) signifies significant renal injury.[15] Clearly, a negative urinalysis does not rule out significant renal injury.

PENETRATING RENAL TRAUMA

Management

The overall management of the urological casualty in Vietnam started on hospital arrival with prompt preoperative resuscitation and control of shock, relief of respiratory distress, and injury evaluation. If renal injury was suspected by either hematuria or location of the wound and missile tract, a high-dose, rapid-infusion (5–10 min) IVP (2 mg/kg iodine contrast) was accomplished. This usually was adequate to define the site of injury and establish the presence and "normalcy" of the opposite kidney within 10 to 20 minutes. Because of the high incidence of serious multiple organ wounds, the nonurological injuries were often more obvious and life threatening, dictating priority treatment. Such patients often went to immediate surgery with incomplete urological evaluation.[2,3]

All patients with penetrating thoracoabdominal wounds and renal wounds were explored transabdominally. Intraoperative, high-dose, one-shot IVP was done in incompletely staged patients with obvious retroperitoneal hematoma and suspected renal injury. Generally, proximal renal vascular control was accomplished prior to renal exploration. Nephrectomy was accomplished for severely or "irreparably" damaged kidneys and, in instances of hemodynamic instability, even if partial nephrectomy or renorrhaphy was technically feasible. In two series[2,3] from Vietnam involving 4 hospitals, urologists reported that the nephrectomy rate varied from 51% to 84%. Debridement, control of bleeding, and partial nephrectomy were other surgical techniques used in managing these wounds. All renal fossae were externally drained. These urologists reported no significant postoperative complications in Vietnam from the surgical management of these renal wounds.

Wound Analysis

Sixty-nine (65%) of 106 renal wounds were caused by missile fragments, 36 (34%) of 106 by bullets, and the cause of 1 was undetermined (Table 2-4). Major complications occurred in 15 (21.7%) of 69 patients with fragment wounds. Of the 26 (37.7%) of 69 fragment renal wounds requiring nephrectomy, 20 (77%) of 26 were emergent at primary treatment in Vietnam, and 6 (23%) of 26 were necessitated by delayed complications in Japan (Table 2-5). The nephrectomy rate in our hands for casualties with renal wounds sustained in Vietnam was 33% (35 of 106 wounds): 15 (42%) of 36 patients with GSWs had nephrectomy and 20 (30%) of 69 with fragment wounds had nephrectomy in Vietnam. In other reports from Vietnam, the nephrectomy rate

TABLE 2-4
PENETRATING WOUNDS

Wounding Agent	No. Wounds	% Total Wounds
Fragments	69	65
Bullets	36	34
Undetermined	1	1
Total Wounds:	**106**	**100**

TABLE 2-5
FRAGMENT WOUNDS OF THE KIDNEY

Category	Patients No.	Patients %
Total Renal Fragment Wounds	69	100.0
Major Complications	15/69	21.7
Nephrectomy	26/69	37.7
Immediate	20/26	77.0
Delayed	6/26	23.0

TABLE 2-6
GUNSHOT WOUNDS OF THE KIDNEY

Category	Patients No.	Patients %
Total Renal Gunshot Wounds	36	100.0
Major Complications	10/36	27.8
Nephrectomy	19/36	52.8
Immediate	15/19	78.9
Delayed	4/19	21.1

for patients with renal wounds varied from 35 (51%) of 65[2] to 74 (84%) of 88 patients.[3] These higher nephrectomy rates may reflect the greater incidence of high-velocity missile wounds and associated severe multiple organ injuries in patients with shock, as well as the surgeon's reluctance to perform partial nephrectomy or renal repair because of the high probability of increasing morbidity and mortality.

In Japan, major complications developed in 10 (27.8%) of the 36 patients with GSWs involving the kidney. The overall nephrectomy rate in this group was 19 (52.8%) of 36 patients, with 4 (21%) of 19 procedures being delayed (Table 2-6). Although GSWs to the kidney were less common, they were associated with a significantly higher overall nephrectomy rate: 52.8% versus 37.7% for fragment wounds, suggesting greater tissue destruction from high-velocity bullets. There was no significant difference in major complications in these two groups.

On the other hand, of the 20 patients who required immediate nephrectomy for fragment wounds, only 1 developed a major complication: death from sepsis from nonrenal causes. Of the 15 patients with GSWs who had immediate nephrectomy in RVN, 3 developed major complications: small bowel obstruction, hemothorax, and wound infection (Table 2-7). This group's overall complication rate (11.4%) and fatality rate (2.7%) were remarkably low.

TABLE 2-7
PENETRATING RENAL INJURIES: COMPLICATIONS OF IMMEDIATE NEPHRECTOMY

Wounding Agent	No. Patients	Complication	Patients With Complication No.	Patients With Complication %
Fragment	20	Sepsis leading to death	1/20	5
Gunshot	15		3/15	20
		Small-bowel obstruction	1/3	
		Hemothorax	1/3	
		Wound infection	1/3	

The broad surgical management of 106 patients with renal wounds is outlined in Table 2-8. Of all 106 patients, nephrectomies were done in 45 (42.5%). The nephrectomy rate in RVN as part of the initial treatment of these 106 patients was 35 (33%) of 106. Delayed nephrectomy was necessary in 10 (22%) of the 45 patients requiring nephrectomy; the procedure was done in less than 10% of all the renal wounds. Partial nephrectomy, debridement, and wound drainage were done in 17 (16%) of 106 of this group. Forty-four (41.5%) of 106 had renal exploration with or without repair, with or without debridement, and with drainage of the renal injury.

Seventeen (16%) of 106 patients with renal wounds had partial nephrectomy in Vietnam immediately following the initial wounding (Table 2-9). There were no early complications; however, major delayed complications developed in 5 (29.4%) of the 17: hemorrhage, infection, or both; 3 with nephrocutaneous fistula; and 2 (11.8%) of 17 required delayed nephrectomy. Delayed nephrectomy was required in 8 (16%) of 48 whose renal wound was treated primarily with exploration or debridement or both, primary repair, and drainage. The increased delayed nephrc-

TABLE 2-8
MANAGEMENT OF 106 PATIENTS WITH RENAL WOUNDS

Procedure	No. Patients	% Patients With Procedure
Total Nephrectomy	45/106	42.5
Early Nephrectomy	35/106	33.0
Delayed Nephrectomy	10/106	9.5
Partial Nephrectomy	17/106	16.0
Exploration, Renorrhaphy, Debridement, and Drainage	44/106	41.5
Totals:	**106**	**100.0**

TABLE 2-9
INITIAL SURGERY AND COMPLICATIONS OF RENAL WOUNDS TREATED BY PARTIAL NEPHRECTOMY

	Patients	
Management	**No.***	**%**
Partial Nephrectomy	17/106	16.0
Delayed Complications	5/17	29.4
Hemorrhage	1	
Infection	1	
Hemorrhage and infection	1	
Nephrocutaneous fistula	3	
Delayed Nephrectomy	2/17	11.8

*Some patients had more than 1 complication

tomy rate (16%) in this latter treatment group is not statistically significant.

In our experience with renal wounds, most kidneys were salvaged: 61 (58%) of 106, but there were major delayed complications in 5 (29%) of 17 treated with partial nephrectomy, including 2 with delayed nephrectomy. Delayed nephrectomy was required in 8 (17%) of 48 following initial treatment of the renal wound with debridement, control of bleeding, and drainage. Sepsis was a major factor in 4 patients. Several delayed complications developed 8, 12, 16, 22, and 28 days after the initial treatment, averaging 2 weeks postsurgery. Meticulous attention to established techniques of renal reconstruction (renorrhaphy) might have reduced the incidence of complications and the need for secondary nephrectomy. These techniques are reviewed below in the Discussion section of this chapter and outlined in Exhibit 2-1.

EXHIBIT 2-1
SURGICAL PRINCIPLES IN RENAL SALVAGE: RENORRHAPHY AND PARTIAL NEPHRECTOMY

- Early renal vascular control
- Complete renal exposure
- Debridement of all devitalized tissue
- Suture hemostasis of bleeding vessels
- Watertight closure of the collecting system
- Coverage of the renal parenchymal defect
- Adequate perirenal drainage

Source: McAninch JW, Santucci RA. Genitourinary trauma. In: Walsh PC, Retik AB, Vaughan ED Jr, Wein AJ, eds. *Campbell's Urology*. Vol 4. 8th ed. Philadelphia, Pa: Saunders; 2002: 3712.

Case Reports

Several case reports are presented that reveal a high incidence of serious multiple organ injuries and the resulting complications associated with renal wounds that penetrate the abdominal cavity. Cases demonstrating myriad complications, including many that required nephrectomy, are reviewed to emphasize the extensive challenges in the management of these wounds.

Case 2-1

F. P., 21 years of age, sustained multiple fragment wounds (MFWs) of the right flank with wounds of the right kidney and liver, and a perforated right colon. At transabdominal exploration, a right colectomy, ileotransverse colostomy, and drainage of a retroperitoneal hematoma were accomplished. Two and one-half weeks later he became septic and developed severe right pyelonephritis and a perinephric abscess. A nephrectomy was done and the flank drained. Four weeks postinjury, a right subphrenic abscess containing 1.5 L of purulent material was drained. He eventually recovered and was evacuated to the continental United States.

Case 2-2

E. R., a 21-year-old soldier, sustained a GSW with perforation of the lower pole of the right kidney and duodenal and pancreatic injuries. The renal injury was debrided, and hemostasis was obtained with suture ligatures. Sump drainage for the perinephric

area was instituted. Fourteen days after the injury he was found to have a proximal right-sided nephrocutaneous fistula. This was considered inoperable at the time of exploration owing to dense bowel adhesions and sepsis. An upper right ureteral transection was unrecognized during the initial surgery. After a right nephrectomy, further convalescence was uneventful.

Case 2-3

R. G. N., a 33-year-old soldier, received a GSW to the abdomen. At laparotomy he had repair of a tear in the mesoappendix and an appendectomy. A contusion of the right kidney was noted. The surgeon made no mention of hematuria or of a perirenal hematoma at that time. Penrose drain was placed in the flank. The initial postoperative course was uncomplicated. Eight days later, he developed mild right costovertebral angle (CVA) pain, and gross total hematuria with marked hypotension. Eight units of whole blood were rapidly administered. An IVP showed no apparent function on the right side with a normal appearing left kidney. Transabdominal laparotomy revealed a wound of the central portion of the right kidney with considerable necrosis, which had been missed on his initial abdominal exploration. After emergency nephrectomy, his further course was uneventful.

Case 2-4

W. H. S., a 21-year-old soldier, suffered fragment wounds of the abdomen from a rocket-propelled grenade. At abdominal exploration, small bowel perforations were repaired. Lacerations of the renal cortex on the right were noted. Penrose drains were placed in the kidney and no effort was made to remove the fragments. He was given antibiotics and 3 units of whole blood. Copious urinary drainage occurred around the Penrose drains for the first few postoperative days. His wound did not appear infected and he was afebrile. On the 11th postoperative day, he became febrile and septic while drainage from the right flank had ceased. His Penrose drains had been partially advanced and were again tweaked, and the wound was explored locally with a large hemostat and digital exploration. A small amount of drainage was obtained. An IVP showed considerable urinary extravasation on the right. A metallic fragment was noted in the region of the right ureteral pelvic junction (UPJ) and there was a fragment within the kidney. The opposite kidney appeared normal. Drains were placed in the flank and an attempt was made to adequately drain the urine by means of ureteral catheter. This drainage was inadequate and the patient remained febrile. He was explored in Japan through a right-flank incision and an examination of the kidney revealed marked ureteral obstruction with considerable reaction around the metallic fragment in the region of the UPJ. The patient had wounds in the upper and mid portions of the kidney with a great deal of necrotic tissue. After nephrectomy, convalescence was uneventful.

Case 2-5

J. E. B., a 26-year-old soldier, incurred fragment wounds of the abdomen. At exploration, small bowel perforations were repaired. A wound to the lower pole of the right kidney was noted, which was not bleeding and nothing further was done. A drain had been placed in the retroperitoneal space and had been removed on the 10th postoperative day. There were no early complications. Twenty-seven days postinjury, he suddenly developed total gross painless hematuria. An IVP showed good function bilaterally, and a metallic fragment was noted in the cortex of the lower pole of the right kidney. There was no urinary extravasation. Panendoscopy revealed blood coming from the right ureteral orifice. He had been on antibiotics for 2 weeks following his injury and antibiotics

were restarted at the time of his bleeding. The following day he developed right CVA pain followed by chills and fever. The repeat IVP was unchanged. He developed classic Gram-negative septicemia and shock, and was treated vigorously with fluids, massive doses of antibiotics, oxygen, and steroids. Blood cultures grew *Pseudomonas*. He developed hemolysis with a large drop in his hematocrit and an emergency right nephrectomy was contemplated, but the patient responded to conservative therapy and eventually became asymptomatic. He was continued on antibiotics until he had been afebrile for 10 days. Subsequently he was discharged and had no further urological problems.

Comment on Case 2-5

This case illustrates a potential problem with a contaminated retained foreign body in an undebrided renal wound.

Case 2-6

F. S. F. incurred MFWs of the left chest and abdomen. The lacerated spleen was removed; the fragmented upper pole of the left kidney was resected; large bowel perforations were repaired and a colostomy performed; in addition, a transthoracic repair of the diaphragm was accomplished. One week after surgery, his subphrenic abscess was drained. One month postinjury, he was found to have a left nephrocutaneous fistula. The wound was debrided again and adequately drained, and further convalescence was without complication.

Case 2-7

E. M. suffered a GSW of the left upper quadrant with the exit wound in the left flank, and a wound of the left arm. At laparotomy, a splenectomy, ligations of bleeding vessels of the pancreas, closure of the gastric perforations, and resection of the lower pole of the left kidney were accomplished. Two weeks postoperatively, the patient became febrile and the left perinephric abscess was drained. Follow-up revealed some residual scarring of the left kidney but good renal function.

Case 2-8

B. R. received GSWs of the flank and lacerations of the spleen, left kidney, stomach, and tail of the pancreas. A splenectomy was done, the pancreatic wound drained, the wound to the stomach closed, and a perirenal hematoma drained. The patient became septic postoperatively and was noted on IVP to have a nephrocutaneous fistula. Seventeen days postinjury, a partial nephrectomy was done. Five days after this, at 22 days postinjury, the patient developed severe bleeding which was treated with emergency nephrectomy.

Case 2-9

A. J. had MFWs of the right lumbar area with perforation of the lower pole of the right kidney and right colon, treated with colostomy and right nephrostomy, following debridement of the kidney. The patient remained septic postoperatively. His nephrostomy tube was removed in Vietnam 2 weeks postinjury without radiographic studies. One week later in Japan he had urinary extravasation and became febrile and septic. Following emergency nephrectomy, further convalescence was uneventful.

Case 2-10

C. W., a 20-year-old soldier, suffered MFWs of the abdomen. He was in profound shock when initially resuscitated, and an exploratory laparotomy showed multiple wounds to the small and large bowel, which were repaired with construction of a left colostomy. He had numerous bleeding sites and required transfusion of 23 units of whole blood. No note was made of injury to the urinary tract. His postoperative course was complicated by persistent fever and upper abdominal left-flank pain. He became severely septic in Japan, and exploration on the 10th postoperative day revealed an epigastric abscess, which was drained with *Aerobacter* and *E coli* being cultured. A small amount of fluid was present in the left pericolic gutter but no actual abscess was found. Because of the severe left-flank pain, a left retrocolic perirenal area was explored, revealing total infarction of the left kidney. There was a great deal of induration about the renal pedicle and it was speculated that the renal artery had been ligated at the time of his abdominal exploration. A nephrectomy was done. His postoperative course was further complicated by recurrent sepsis, abdominal abscesses, and eventual death from generalized sepsis.

Case 2-11

J. H., a 20-year-old soldier, had GSWs of the left abdomen with destruction of the lower pole of the left kidney. At transabdominal surgery, he had a partial nephrectomy, repair of injuries to the small and large bowel, and construction of left colostomy and retroperitoneal Penrose drainage. He drained profuse amounts of urine from his left flank, and after 10 days the drains were removed. Urinary drainage persisted from the left flank. On postoperative day 26, urological consultation was obtained in Japan; workup revealed good bilateral renal function on IVP with evidence of extravasation of urine from the lower pole of the left kidney. The patient was given a light anesthetic, and the drain site was probed with no significant evidence of urinoma. Some drains were placed in the region of the lower pole, and after 3 days the drainage markedly decreased. The drains were advanced, removed on the 6th day, and no further drainage ensued. Follow-up IVP showed a very small, localized extravasation of urine. This disappeared on serial follow-up studies, and there were no further complications.

DISCUSSION

Renal wounds in Vietnam were encountered in approximately 9% of abdominal cavity wounds, with a mortality of 7.8% from abdominal renal wounds. Between 31% and 35% of urological wounds in Vietnam involved the kidney, and, as stated above, the nephrectomy rate reported by urologists was 51% to 84%.[2,3] Many of these wounds were from high-velocity bullets and fragments, which caused extensive, high-grade, life-threatening, renal, and multiple other contaminating intraabdominal visceral wounds.

The overall management of the urological casualty in Vietnam and general management in treating the renal injuries have been discussed above in this chapter in the Management section under Penetrating Renal Trauma. Because of the severe, life-threatening, high incidence (80%–100%) of concomitant injury to intraperitoneal viscera, transabdominal exploratory laparotomy was believed to be mandatory for all renal wounds in Vietnam,[1–3] and, during that time, in the civilian sector.[7,8] The mortality was closely related to the number of intraabdominal viscera damaged, not from the renal wound or wounds per se. Wounds of the

hepatoduodenal ligament carried the highest mortality, and wounds of the inferior vena cava and aorta had mortality rates of 55% and 60%, respectively.[1,7,8]

In the civilian sector, many still believe that all penetrating renal GSWs should be explored.[7,8,15,16] Currently in many major civilian trauma centers, however, hemodynamically stable patients with abdominal renal wounds are initially staged by contrast-enhanced spiral CT. Patients with wounds made by low-velocity missiles and without significant other abdominal visceral or vascular injury and life-threatening major renal trauma are initially treated expectantly without surgery.[10,11,17] One group[10] has managed 24% of GSWs nonoperatively with well-staged injuries in carefully selected patients. However, such an approach to the combat casualty with renal wounds is neither feasible nor practical.

To reiterate, the incidence of nephrectomy in published data from Vietnam for renal wounds was from 51%[2] to 84%.[3] In our Japan experience, 35 (33%) of 106 patients with renal wounds had already had immediate nephrectomy in Vietnam. In these patients, whose renal wounds were abdominal, the 2 most common reasons for nephrectomy were[2,3]

1. hemodynamic patient instability, often with low body temperature and coagulopathy, and
2. "irreparable" renal injury.

The reasons for a nephrectomy for traumatic renal injuries at a major civilian trauma center were recently reviewed in 26 patients: 77% had nephrectomy for major irreparable parenchymal and vascular or combined renal injury (grades IV, V, see Figure 2-2), and the remaining 23% had nephrectomy for hemodynamic instability in otherwise reconstructable kidneys.[18] The high nephrectomy rates in Vietnam, presumably primarily for hemodynamic instability, not only reflect the severity of wounds but may well be a result of significant improvements in casualty retrieval and resuscitation techniques, allowing for the more-severely wounded to reach the operating room and surgery.

The nephrectomy rate from extensive bleeding at renal exploration for renal trauma can be reduced from 56% to 12% by obtaining preliminary transperitoneal vascular control of the renal vessels before opening Gerota's fascia.[10,19] This surgical approach not only facilitates the control of renal bleeding at renal exploration but also allows for renal exploration with confidence in cases of unstaged renal injury with discovery of a significant retroperitoneal hematoma. In Vietnam, most urologists presumably employed this "early renal vascular control" technique prior to renal exploration, but many renal explorations and nephrectomies were done by general surgeons. Nephrectomy was often done because of the higher complication rate with attempted renal salvage when renal injury was associated with injuries to the liver, colon, stomach, pancreas, and other organs. More recently in the civilian trauma community, renal repair has proven successful despite these multiple other abdominal organ wounds.[20,21]

Renal Salvage Procedures

Current recommended techniques of renal salvage after traumatic renal injury include renal reconstruction for parenchymal laceration (renorrhaphy) and partial nephrectomy for renal polar injuries (see Exhibit 2-1).[17,22] The key surgical techniques employed in renorrhaphy are

- complete exposure of the kidney,
- sharp excision with a scalpel blade of all ischemic or devitalized parenchyma (complete debridement),
- hemostasis of bleeding vessels with absorbable 4-0 chromic sutures,
- watertight closure of the collecting system, and
- coverage or approximation of the parenchymal defect margins (3-0 absorbable suture) using any remaining renal capsule and absorbable gelatin bolsters (GelFoam, Upjohn Co, Kalamazoo, Mich).

Partial nephrectomy is used for polar injuries that cannot be reconstructed. All nonviable tissue should be sharply excised, and hemostasis and closure of the collecting system should be done as in renorrhaphy. Stenting may be used for pelvic or ureteropelvic lacerations. After polar resection of the kidney, in which the capsule has been stripped off, the open parenchyma can be covered with a pedicle flap of omentum. When this is not feasible, a peritoneal graft, polyglycolic mesh, or retroperitoneal fat can be used. Warm ischemia time of 30 to 45 minutes is tolerated if occlusion of the renal artery is needed to control bleeding. External perirenal drainage should be used after renal reconstruction or partial nephrectomy.

Delayed complications following renorrhaphy or partial nephrectomy or from nonoperative management are listed in Exhibit 2-2. The complication rate increases with high-grade renal injury and with multiple injuries to associated organs. The most significant complications that we experienced in Japan with renal wounds in casualties of the Vietnam War included

- persistent urinary extravasation, including urinoma and nephrocutaneous fistula;
- usually associated with perinephric abscess, pyelonephritis, and/or generalized sepsis; and
- hemorrhage, often massive and delayed (occurring ≤ 27 d postinjury) and usually associated with infection and sepsis.

EXHIBIT 2-2
DELAYED COMPLICATIONS OF RENAL TRAUMA

- Urinary extravasation: urinoma, fistula
- Bleeding
- Infection: intrarenal, abscess, systemic sepsis
- Loss of renal function: infarction, atrophy
- Obstruction
- Hypertension

Source: McAninch JW, Santucci RA. Genitourinary trauma. In: Walsh PC, Retik AB, Vaughan ED Jr, Wein AJ, eds. *Campbell's Urology*. Vol 4. 8th ed. Philadelphia, Pa: Saunders; 2002: 3713–3714.

The initial management of renal bleeding should be conservative with fluids and transfusion. But if the conservative approach is unsuccessful, then clearly nephrectomy may be indicated. In the nonbattlefield situation, renal angiography can often localize the bleeding vessel and bleeding may be controlled by embolization.

Complications That Necessitated Delayed Nephrectomy

Delayed nephrectomy in Japan was required to manage many of these complications in 10 (9.5%) of 106 patients with renal wounds: for massive delayed hemorrhage with sepsis (either localized or systemic) in 5 patients, and in 5 for systemic sepsis associated with intrarenal infection, and perirenal and abdominal abscesses. Most of these patients had significant renal and associated contaminating abdominal wounds with devitalized tissue; often bathed in urine, blood, and intestinal contents; and often arrived in Japan with obstructing, poorly managed Penrose drains. All these factors created an ideal milieu for local abscess, perinephric and intrarenal infection, generalized sepsis, and delayed bleeding. Many of these patients had a prolonged postinjury course and were initially depleted of both nutrition and nitrogen, had electrolyte imbalances, and often had various degrees of coagulopathy. Consequently, we found that nephrectomy was often the wiser choice in managing these complications and often was lifesaving. There was 1 death in the delayed nephrectomy group from nonrenal cause in Japan.

Of the many patients with nephrocutaneous fistula, only 1 required nephrectomy for persistent renal and perirenal infection, generalized sepsis, and ureteral obstruction. Generally, patients with nephrocutaneous fistula or urinoma or both, and without other organ and systemic problems, healed the urine leak without sequelae after debridement and enhanced external perirenal drainage.

Routinely in RVN, perirenal drainage was established with Penrose drains. Patients often arrived in Japan with obstructed Penrose drains (urine and purulent material had accumulated behind these drains, contributing to sepsis and poor healing). The poor management of the Penrose drains was due in part to the prolonged evacuation system, in which patients were placed in a “holding area” (an area of secondary care) prior to evacuation to Japan. Often 48 to 72 hours elapsed between when the patient last received definitive care by a urologist or surgeon in Vietnam and when first seen in Japan. Currently, myriad soft, tubular drains with fenestrations and suction capability are available and are more ideal for wound drainage.

Several factors contributed to the major complications that we managed in Japan, starting with the severe contaminating and devitalizing effects of the initial wounds, which usually involved multivisceral organ systems. Many of the surgeons and urologists who managed these wounds had limited prior trauma experience. Incomplete debridement, lack of complete hemostasis, poor dependent drainage and monitoring of drains, and at times missed organ injuries contributed to sepsis and delayed hemorrhage. Antibiotics were liberally used

but the variety and spectrum of effective agents was considerably limited—as opposed to the more effective agents currently available today. The urologists' ability to establish internal and renal drainage was hindered by the poor quality of tubes and stents available for such drainage, and the general surgeons' unfamiliarity with such equipment and techniques contributed to this problem. Imaging and staging of renal injuries were restricted by the shortcomings of the Vietnam-era IVP. The current expertise of the interventional radiologist and the large variety of percutaneous techniques used for urinary diversion and drainage of urinomas and abscess cavities were not then available. The lack of longitudinal professional supervision of the casualty and the need for movement and the time involved in the evacuation of the wounded can be contributing factors to these complications. Notwithstanding these varied factors, however, we believe that the overall management of patients who incurred renal wounds in Vietnam was superb, as the low mortality rate reflects.

BLUNT TRAUMA

Wound Analysis

The renal injuries of 26 (19.7%) of 132 patients were secondary to blunt trauma (Table 2-10). Many patients with mild blunt renal injuries were treated in RVN and not medically evacuated to Japan. Vehicular accidents, both land and aircraft, accounted for 9 (34.6%) of 26 blunt renal injuries. The circumstances of 2 injuries were not established.

In addition, 9 (34.6%) of 26 of these patients had injuries involving other organs (Table 2-11). Fractures were present in 5 (19.2%) patients. Only 1 patient had a ruptured spleen and 1 had a ruptured liver. The presence of only 1

TABLE 2-10
CAUSES OF BLUNT RENAL INJURIES

Cause of Injury	No. Patients
Land Vehicles	6
Blast Injuries	4
Fall	4
Blow	4
Aircraft Accidents	3
Football	2
Crush	1
Unknown	2
Total Patients:	**26**

TABLE 2-11
BLUNT RENAL TRAUMA: ASSOCIATED INJURIES

Associated Injuries	No. Patients	% With Associated Injuries
Total Injuries to Other Organs	9/26	34.6
Fractures	5	
Head	1	
Spleen	1	
Liver	1	
Lung/Chest Wall	1	

patient with a head injury might indicate that there were presumably many more fatal crush injuries and blast injuries of the kidney and other organs (ie, most of the severely wounded casualties also had head injuries that caused early deaths). The Japan experience was typical of patients surviving blunt trauma.

Twelve delayed major complications occurred in Japan in 7 (27%) of 26 patients with blunt renal injury (Table 2-12). Significant gross hematuria occurred in 5 (19.2%) of 26 of patients (2 required delayed nephrectomy) and 2 had urinary extravasation with gross hematuria. Renal atrophy occurred in only one case.

TABLE 2-12
BLUNT RENAL INJURIES: DELAYED COMPLICATIONS

	Patients	
	No.	%
Patients* With Complications	7/26	27
Complication		
Gross Hematuria	5	
Urinary Extravasation	2	
Perirenal Infection	1	
Painful Flank Mass	2	
Renal Atrophy	1	
Atelectasis	1	
Total Complications:	**12**	

*Some patients had more than 1 complication

The surgical treatment of patients with blunt renal injuries is summarized in Table 2-13. Immediate surgery (abdominal renal exploration) was required in 5 (19.2%) of the 26 patients: 3 with nephrectomy, 1 with splenectomy, and 1 with repair of a lacerated liver. Delayed surgery was necessary in 4 (15.4%) of 26 of patients: 3 received nephrectomy and 1, partial nephrectomy. Overall, 9 (34.6%) of 26 patients had abdominal renal surgery with a nephrectomy in 6 (23.1%) of 26, of which 3 were done at initial exploration and the remaining 3 as a delayed procedure. The high incidence of surgery and nephrectomy reflects the severity of these wounds and the selection of patients for evacuation. Three delayed nephrectomies were accomplished in Japan. Two of these patients had severe central injury to the kidney involving the renal vasculature and parenchyma (grade IV–V injury [contemporary staging—JNW, au]; see Figure 2-2): 1 with massive hemorrhage and 1 with perirenal hematoma and urinary extravasation.

TABLE 2-13
SURGERY OF BLUNT RENAL INJURIES

Timing and Type of Procedure	Patients	
	No.	%
Immediate Abdominal/ Renal Exploration	5/26	19.2
Nephrectomy	3	
Splenectomy	1	
Repair of liver lacerations	1	
Delayed Surgery	4/26	15.4
Nephrectomy	3	
Partial nephrectomy	1	
Total Nephrectomies:	**6/26**	**23.1**
Total Surgical Operations:	**9/26**	**34.1**

Case Reports

Several illustrative cases are reviewed below; they demonstrate the wide spectrum of minor and major renal injury, the clinical manifestations, and the complications that can occur from blunt renal trauma. The management of these cases might have been different in a peacetime environment, especially with the current ability to accurately stage and define the grade of renal injury by contrast-enhanced CT.

Case 2-12

A. R. B., a 20-year-old soldier, fell while carrying a large block of ice in RVN, striking his left upper quadrant 13 days prior to admission in Japan. The patient had been hospitalized for gross hematuria and transfused with 2 units of blood. The gross hematuria had essentially ceased by the 4th day postinjury.

During evacuation to Japan, the patient developed recurrent gross hematuria. His hematocrit was 17 on arrival in Japan; he was normotensive with tachycardia. A tender left-flank mass was detected. His urine was blood-tinged. He was transfused with 6 units of whole blood, and his urine immediately became increasingly bloody; blood clots in the bladder caused acute urinary retention. An IVP was of poor quality but showed bilateral function with no obvious urinary extravasation. He had a marked ileus. Following multiple blood transfusions, he required a suprapubic cystotomy to evacuate rapidly forming clots from his bladder. Subsequent transabdominal exploration utilizing the controlled approach to the renal pedicle revealed an extensive fracture of the middle of the left kidney with major vascular damage [grade IV–V injury, contemporary staging—JNW, au]. An emergency nephrectomy was accomplished, as repair to the vascular injury was not feasible.

Case 2-13

R. B., a 19-year-old soldier, developed gross hematuria after mild abdominal trauma. An IVP demonstrated a 15-cm calcified cystic lesion in the left upper abdomen, with nonfunction of the left kidney and compensatory hypertrophy of a normal right kidney. Past history revealed that he had been in an automobile accident at age 9 with transient gross hematuria. His symptoms had cleared and he had no further studies at that time. Subsequent to that event, he had had periodic mild left upper abdominal pain. The X-ray findings were consistent with a perirenal pseudocyst with calcification secondary to his previous renal injury. Transabdominal exploration revealed a large calcified perirenal pseudocyst with a fibrotic-appearing ureter running through the cyst cavity. The kidney had been destroyed and nephrectomy was accomplished. His recovery was uneventful.

Comment on Case 2-13

This case represents an unusual complication secondary to renal trauma.

Case 2-14

N. C. B., a 21-year-old soldier, had no urological problems prior to a fall during which his left flank was bluntly traumatized. He denied initial hematuria and returned to his normal duty. Nine days posttrauma, he developed total, gross, painless, hematuria

that lasted 6 days, ceased, and then recurred 18 days later. Subsequently he had daily gross hematuria that varied in color from light bloody to burgundy wine, and on 2 occasions, he had passed painful "wormlike" clots. An IVP, retrograde urogram, and renal arteriography were done and all were thought to be normal. Cystoscopy at the time of bleeding revealed bloody efflux from the left ureteral orifice. Urine cultures and evaluation for tuberculosis were unremarkable. The patient had no evidence of coagulopathy. There was no evidence of sickle cell trait or disease. This patient had no other complaints and his gross and microscopic hematuria subsided. He was discharged.

Comment on Case 2-14

The most likely cause of his hematuria was contusion. In well-staged patients, gross hematuria has occasionally been associated with contusion only. Renal angiography was accomplished to rule out any arteriovenous abnormality.

Case 2-15

M. F., a 22-year-old soldier, fell 25 feet from a tower and incurred blunt trauma to the left flank. He initially presented with gross hematuria, which subsided on bedrest; his hematocrit and vital signs were normal on presentation. Subsequently, he had a few episodes of blood-tinged urine with mild tenderness of the left flank after ambulation; he was evacuated to Japan 28 days later because of persistent pain. On physical examination he had a tender mass in the left flank with microhematuria and normal renal function. An IVP revealed a normal right upper tract and massive extravasation of urine around the left kidney with a single upper functioning calyx. Transabdominal renal exploration was performed with standard vascular approach to the renal pedicle. After reflecting the left colon medially, a large hematoma and a urinoma were evacuated. The lower two thirds of the left kidney was totally infarcted. Following a nephrectomy, convalescence was uneventful.

Comment on Case 2-15

This patient obviously had a grade IV renal injury (contemporary staging—JNW, au) that was missed on initial evaluation in Vietnam. This case reflects the need for accurate staging of patients with blunt renal trauma and gross hematuria.

Case 2-16

R. M., a 23-year-old soldier, was struck by a vehicle and sustained crush injuries of the right lateral chest and the right upper abdomen. He had gross hematuria and normal and stable vital signs and hematocrit. The gross hematuria subsided over the first 48 hours of bedrest. An IVP revealed a normal-appearing left kidney and good function on the right with moderate urinary extravasation. He was placed on prophylactic antibacterial medications, and his right-flank discomfort improved. On the 7th day postinjury, he developed fever of 101ºF with increasing pain and tenderness. His IVP revealed an expanding mass on the right with urinary extravasation. An exploration in Vietnam through a right-flank incision revealed a large urinoma, which was appropriately drained. The kidney appeared viable, and a large renal laceration was repaired. R. M. was maintained on antibiotics, and his postoperative course was uncomplicated.

DISCUSSION

The causes and mechanisms of blunt renal injuries have been reviewed earlier in this chapter. Hematuria is the best indicator of traumatic renal injury. However, the degree of hematuria and the severity of renal injury do not always correlate, although gross hematuria is usually associated with major renal parenchymal injury.

Currently, contrast-enhanced CT is the most often used (in civilian centers) and most accurate imaging modality to stage renal trauma according to the anatomical definition of injury and classification of severity (grade) of injury, as discussed earlier in this chapter. Currently, CT is not available in the 1st echelon of treatment of the battlefield casualty, and renal trauma is still staged by IVP.

The Renal Trauma Group at San Francisco General Hospital recognized that when using hematuria as the only indicator for renal injury, IVP and other studies revealed a low incidence of renal abnormalities. This group prospectively evaluated indications for radiographic imaging. From this study, they concluded that all adult patients with blunt trauma with gross hematuria, and patients with microhematuria and shock (systolic blood pressure < 90 mm Hg anytime during evaluation and resuscitation), should undergo renal imaging—usually with contrast-enhanced CT. The incidence of major injuries in the group with gross hematuria was 12.5%. Adults with microscopic hematuria without shock need no imaging but do need clinical follow-up.[23,24] These guidelines are the current "gold standard" for the indications for radiographic imaging of the patient with blunt renal trauma.

Of blunt renal injuries, 75% to 85% may be classified as minor, corresponding to grades I to III of the Organic Injury Scale (see Table 2-3). There is little controversy today about the usefulness of conservative management of these injuries. Major renal injuries comprise the remaining 15% of cases, of which 5% are grade V [contemporary staging—JNW, au]. A hemodynamically stable patient with a well-staged injury by CT can usually be managed without renal exploration. Although grades IV and V injuries more frequently require surgical exploration, many of these patients (without pedicle vascular injury) can be managed nonoperatively if their injuries are carefully staged and selected. Patients managed nonoperatively must be hospitalized at bedrest until gross hematuria abates, and they require periodic reimaging and very close serial monitoring for complications.[11,25] Urological complications in these patients may often be approached by minimally invasive endourological technique (ie, retrograde ureteral stenting for urinoma). At this time, many systematic inadequacies (eg, the lack of equipment, definitive staging by CT, trained trauma personnel and team), and unpredictable variables (eg, the instability of the environment—often with the need for distant evacuation) make such an approach impractical in the early management of the combat casualty with major blunt renal injury or in those with major complications. During the Vietnam War, nonoperative management of major, high-grade, blunt renal injuries was clearly not a consideration.

EXHIBIT 2-3
POSTTRAUMATIC INDICATIONS FOR RENAL SURGERY

Absolute
- Persistent renal bleeding
- Expanding perirenal hematoma
- Pulsatile perirenal hematoma
- Bilateral renal artery occlusion

Relative
- Urinary extravasation
- Nonviable tissue
- Arterial injury
- Incomplete staging
- Associated injuries

Sources: (1) McAninch JW, Santucci RA. Genitourinary trauma. In: Walsh PC, Retik AB, Vaughan ED Jr, Wein AJ, eds. *Campbell's Urology*. Vol 4. 8th ed. Philadelphia, Pa: Saunders; 2002: 3711. (2) McAninch JW. Genitourinary trauma: Current approaches of management. Presented at the American Urological Association 98th Annual Meeting; 29 April 2003; Chicago, Ill. Postgraduate Course 49.

The numerous indications for renal exploration following blunt or penetrating renal injury can be separated into absolute and relative[10,24] categories (Exhibit 2-3). In general, all penetrating renal wounds in combat are surgically explored. The unstable patient from renal hemorrhage or with an expanding or pulsatile hematoma at laparotomy clearly requires surgery, as does the rare patient with bilateral renal artery occlusion. Deep lacerations with urinary extravasation and with associated injuries, and segmental renal artery injuries, both with substantial nonviable tissue, often will resolve quicker with debridement and reconstruction.[26] On the other hand, urinary extravasation from grade IV laceration without other associated injuries will often respond to nonoperative management.[27] When renal injury is obvious (hematuria and retroperitoneal hematoma) in the incompletely staged patient at laparotomy, if single-shot intraoperative IVP is abnormal, then renal exploration allows for complete staging and reconstruction of renal injury.

Operative management of the acutely injured kidney requires a defined overall operative plan with careful attention to details. Surgical exploration should be through a midline transabdominal incision, which provides access to the great vessels for early vascular control and permits identification and repair of unexpected associated injuries[10,19] The specific details of obtaining early control over the renal vasculature can be found in several publications.[10,19,28] This approach for managing traumatic renal injuries and their complications was employed by most urologists in Vietnam and by us in Japan. Recommended techniques of renal salvage and reconstruction have been reviewed above in this chapter (also see Exhibit 2-1).

The delayed complications of renal trauma from either surgical intervention or nonoperative management are discussed above in this chapter (also see Exhibit 2-2 and Table 2-12). Seven patients developed 12 delayed complications in Japan, the most serious being significant gross hematuria and urinary extravasation. Among the 26 patients in the delayed complications group, 5 of the 6 who required nephrectomy had high-grade (grade IV–V [contemporary staging—JNW, au]) renal injury, as did the 1 patient treated with partial nephrectomy, reflecting the severe degree of trauma. To reiterate, the delayed complications indicate not only (1) the severity of initial traumatic injury but also (2) the limitations of the IVP in accurate staging of the extent of injury and (3) problems of evacuation and ambulation

of patients who have poorly defined major renal injury. Such patients need serial monitoring by an experienced nursing team that is closely supervised by a urologist.

CONCLUSIONS AND EPILOGUE

During the Vietnam War, approximately one third of all battlefield urological injuries involved the kidney; about 80% of these were renal wounds, most often made by fragmentation devices. The overall mortality from abdominal renal wounds was 7.5% and the incidence of nephrectomy varied from 51% to 84%. However, the injury pattern during the Persian Gulf War was different, showing a marked reduction in the incidence of abdominal renal wounds and a shift to pelvic and genital wounds (ie, 17% renal vs 83% pelvic and genital). The most plausible explanation for this shift from abdominal to pelvic–genital wounds is the ubiquitous wearing of the "flak jacket" by US military personnel.[29] This jacket provides superb protection to the thorax and upper abdomen from penetrating fragment wounds. Urologists made several anecdotal reports of fragments found in flak jackets at the abdominal and flank locations. An obvious conclusion from this experience is that the high prevalence of use of the flak jacket during modern combat operations will significantly reduce the incidence of renal and associated upper abdominal wounds, substantially decreasing renal injury, the need for nephrectomy, and death from abdominal renal wounds.

The evaluation of renal trauma has to be tailored to the hospital location and setting, the available diagnostic and specialty equipment, the expertise of the medical personnel, and ultimately the condition of the patient on presentation at the hospital. The key to the rational management of the renal trauma patient is accurate, precise definition of the extent of renal damage either by (1) operative controlled abdominal renal exploration, primarily in the unstable patient with penetrating abdominal renal wounds, or (2) radiological imaging (preferably contrast-enhanced CT) of the hemodynamically stable patient, who is most often injured from blunt abdominal renal trauma.

In the Vietnam era, the IVP was the prime modality available for renal imaging and the staging of renal trauma. This study was usually adequate to define the side of injury and establish the presence and "normalcy" of the contralateral kidney. Since the 1990s, contrast-enhanced CT has become the preferred technique for imaging the patient with renal trauma. The limitations of IVP are

- a low sensitivity (approximately 25% of patients with major renal injuries have "normal" urograms), and
- common nonspecific findings, including delayed visualization of renal collecting systems and irregular cortical margins.

On IVP, only nonfunction and extravasation are uniformly associated with major renal trauma.[15] However, the high-dose, rapid-infusion IVP is still indicated and useful in imaging the casualty with renal trauma if

- CT is not available;
- the patient is severely injured, is hemodynamically unstable, and requires immediate surgery; and
- an unexpected retroperitoneal or perirenal hematoma is found at abdominal exploration.

Today, the precise staging of renal trauma is best and most often accomplished by contrast-enhanced CT. This imaging modality is ideally suited for evaluating the hemodynamically stable casualty with renal trauma. The current indications for radiographic imaging of all adult patients with blunt trauma are[23,24]

- gross hematuria,
- microhematuria and shock, and
- high-risk mechanism of injury.

Currently in the wartime combat medical support units, CT scanning is available in some of the Army's combat support hospitals and in the Navy's hospital ships. When indicated and available, contrast-enhanced CT should be used in the definitive staging of the renal trauma casualty, so that patients who are candidates for operative and nonoperative management can be more clearly defined.

Unstable patients selected for nonoperative management of major renal injuries should not be placed in the evacuation chain. Additionally, patients treated primarily with observation need close serial monitoring and periodic reimaging by an experienced team under the supervision of a urologist. Sometimes the indication for renal exploration will evolve over several days, dictated by subtle changes in the patient's status as observed by the urologist. Currently, transabdominal surgical exploration remains the "standard of care" for combat-incurred penetrating abdominal renal missile trauma.

REFERENCES

1. Hardaway RM III. Vietnam wound analysis. *J Trauma*. 1978;18(9):635–643.
2. Salvatierra O Jr, Rigdon WO, Norris DM, Brady TW. Vietnam experience with 252 urological war injuries. *J Urol*. 1969;101:615–620.
3. Selikowitz SM. Penetrating high velocity genito-urinary injuries, II: Ureteral, lower tract, and genital wounds. *Urology*. 1977;9(5):493–499.
4. Hutton JE, Rich NM. Wounding and wound ballistics. In: McAninch JW, ed. *Traumatic and Reconstructive Urology.* Philadelphia, Pa: WB Saunders; 1996: 3–25.
5. Bellamy RF, Zajtchuk R, eds. *Conventional Warfare: Ballistic, Blast, and Burn Injuries.* In: Zajtchuk R, Bellamy RF, eds. *Textbook of Military Medicine.* Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 1990.
6. Whelan TJ Jr, ed. Missile-caused wounds. In: Whelan TJ Jr, ed. *Emergency War Surgery.* 1st US Rev. Washington, DC: Department of Defense, US Government Printing Office; 1975: 9–17.
7. Carlton CE Jr, Scott RS Jr. Penetrating renal injuries: An analysis of 100 cases. *J Urol*. 1960;84:599–603.
8. Scott RS Jr, Carlton CE Jr, Goldman M. Penetrating Injuries of the kidney: An analysis of 181 patients. *J Urol*. 1969;101:247–253.

9. Bretan PN Jr, McAninch JW, Federle MP, Jeffrey RB Jr. Computerized tomographic staging of renal trauma: 85 consecutive cases. *J Urol*. 1986;136:561–565.
10. McAninch JW, Carroll PR, Klosterman PW, et al. Renal reconstruction after injury. *J Urol*. 1991;115:932–934.
11. Santucci RA, McAninch JW. Diagnosis and management of renal trauma: Past, present and future. *J Am Coll Surg*. 2000;191:44326th451.
12. Moore EE, Shackford SR, Pachter HL, et al Organ injury scaling: Spleen, liver, and kidney. *J Trauma*. 1989;29:1664–1666.
13. Morey AL, McAninch JW, Tiller BK, et al. Single shot intraoperative excretory urography for the immediate evaluation of renal trauma. *J Urol*. 1999;161:1008–1092.
14. Cass AS. Renovascular injuries from external trauma. *Urol Clin North Am.* 1989;16:213–220.
15. Carroll PR, McAninch JW. Operative indications in penetrating renal. *J Trauma*. 1985;25:587–592.
16. Moore EE, Moore JB, Vandozer-Moore S, et al. Mandatory laparotomy for gunshot wound penetrating the abdomen. *Am J Surg*. 1980;140:847–851.
17. McAninch JW, Santucci RA. Genitourinary trauma. In: Walsh PC, Retik AB, Vaughan ED Jr, Wein AJ, eds. *Campbell's Urology.* Vol 4. 8th ed. Philadelphia, Pa: Saunders; 2002: 3707–3744.
18. Nash PA, Bruce JE, McAninch JW. Nephrectomy for traumatic renal injury. *J Urol*. 1995;153:609–611.
19. McAninch JW, Carroll PR. Renal trauma: Kidney preservation through improved vascular control: A refined approach. *J Trauma*. 1982;22:285–289.
20. Rosen MA, McAninch JW. Management of combined renal and pancreatic trauma. *J Urol*. 1994;152:22–25.
21. Wessells H, McAninch JW. Effect of colon injury on the management of simultaneous renal trauma. *J Urol*. 1996;155:1852–1856.
22. Wessels H. *Evaluation and Management of Renal Trauma in the 21st Century*. In: American Urological Association. *AUA Update Series, Lesson 30.* Vol 21. Houston, Tex: American Urological Association Inc, Office of Education. 2002: 234–239.
23. Miller KS, McAninch JW. Radiographic assessment of renal trauma: Our 15-year experience. *J Urol*. 1995:154:352–355.
24. McAninch JW. Genitourinary trauma: Current approaches of management. Presented at the American Urological Association 98th Annual Meeting; 29 April 2003; Chicago, Ill. Postgraduate Course 49.
25. Altman AL, Haas C, Dinchman KH, Spirnak JP, McAninch JW. Selective nonoperative management of blunt grade 5 renal injury. *J Urol*. 2000;164:27–31.
26. Hussman DA, Gilling PJ, Perry MO, et al. Major renal lacerations with devitalized fragments following blunt abdominal trauma: A comparison between nonoperative (expectant) versus surgical management. *J Urol*. 1993;150:1774–1777.
27. Matthews LA, Smith EM, Spirnak JP. Nonoperative treatment of major blunt renal lacerations with urinary extravasation. *J Urol*. 1997;157:2056–2058.
28. Scott RF Jr, Selzman HM. Complications of nephrectomy: Review of 450 patients and a description of a modification of the transperitoneal approach. *J Urol*. 1966;95:307–312.
29. Thompson IM, Flaherty SF, Morey AF. Battlefield urologic injuries: The Gulf War experience. *J Am Coll Surg*. 1998;187:139–141.