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UROLOGICAL EMERGENCIES

A PRACTICAL GUIDE

Edited by

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Dedication

To B.C. and C.L.W.

Preface

The changing paradigms of health care delivery require that the management of more and more complex problems takes place in the emergency department and the offices of primary care providers. A cadre of emergency physicians with limited urological training is being called upon to diagnose and treat many acute conditions of the genitourinary tract. Furthermore, the anticipated shortage of urologists, in conjunction with increased use of physician extenders within the urological community, will further limit the availability of urgent urological consultation. *Urological Emergencies: A Practical Guide* is intended to summarize the optimal management of urgent and emergent urological conditions so that the incredible improvements in the acute management of urological problems gained over the last decades can be easily accessible in one volume.

Injury is the leading cause of death in people younger than 44 years of age. The worldwide burden of disease resulting from trauma will increase immensely in the 21st century as a result of wartime injuries and motor vehicle accidents in all parts of the globe. Few nations have trauma systems in place that can rival our own, and thus mortality and disability resulting from trauma in nations with sudden expansion in vehicular traffic will be far higher than in North America. Severe renal injuries are immediately life threatening, and proper recognition of these requires appropriate criteria for staging and the availability of accurate imaging modalities. Lower urinary tract trauma, if unrecognized or mismanaged, can lead to early complications as well as permanent disability and dysfunction from disruption of essential neural, anatomical, and vascular structures of the pelvis.

Mortality from acute injury and infection is so rare in the developed world that the main causes of death in adults are cardiovascular disease and cancer. As a result of the aging of the adult population and the epidemic of obesity and type 2 diabetes mellitus, a dramatic increase in infectious, vascular, and obstructive urological emergencies in the United States is expected. In the developing world, obstructive uropathy, infected stones, and urosepsis remain major sources of morbidity and mortality. Differentiating between acute pyelonephritis and infection caused by an obstructed ureter is essential for proper triage and successful treatment. Identifying Fournier's gangrene in a timely fashion is of paramount importance.

Surgical error remains an irreducible feature of urological practice. Although simulators and systems-based approaches may one day reduce complication rates, iatrogenic injuries are an important problem in ureteral, bladder, and urethral diseases. Lessons from trauma management as well as innovations in endoscopic techniques have allowed urologists to avoid surgical solutions in many cases. The appropriate supportive and medical care must be understood by those in direct contact with the patient.

Congenital anomalies of the genitourinary tract carry a disproportionate risk of coexisting organ system abnormalities that require a highly multidisciplinary team approach to avoid death, permanent disfigurement, or irreversible cosmetic consequences. Despite prenatal sonography, many lower urinary tract anomalies are discovered only at birth. New concepts in the assignment of gender and the basis of gender have dramatically changed the landscape for cases of ambiguous genitalia.

The chapters in *Urological Emergencies: A Practical Guide* are organized by pathophysiology rather than organ system, which allows the reader to develop approaches to the care of patients with acute urological conditions based on mechanism of disease. Nationally and internationally recognized experts have provided up-to-date, evidence-based descriptions of the appropriate diagnostic and therapeutic considerations on topics of traumatic, infectious, obstructive, hemorrhagic, iatrogenic, vascular, and congenital urological emergencies. The relevant pathophysiological background and epidemiology are reviewed, necessary diagnostic tests are recommended, and detailed medical, surgical, and endourological management approaches are provided. These include advances in diagnostic testing and radiographic imaging, nonoperative treatment of acute injuries, endoscopic, angiographic, and percutaneous interventions for obstruction, bleeding, and abscess.

It is hoped that *Urological Emergencies: A Practical Guide* will serve as an authoritative bedside resource for urology residents, practicing urologists, emergency medicine trainees and practitioners, and primary care providers without immediate access to urological consultation.

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I would like to acknowledge Richard Drews for his diligence and persistence.

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I

Urogenital Trauma

1 Diagnosis and Treatment of Renal Trauma

Dan Rosenstein, MD, FRCSC
and Jack W. McAninch, MD

Contents

INTRODUCTION

The kidney is the most frequently injured genitourinary organ because of external trauma and is involved in as many as 5% of abdominal trauma cases. Although the majority of injuries are minor contusions, renal trauma may occasionally represent a true life-threatening emergency. Advances in staging techniques (resulting from increased use of computed tomographic [CT] scanning) as well as increased awareness of the kidney's capacity for healing have permitted the majority of these injuries to be successfully managed nonoperatively.

Nonetheless, certain severely injured kidneys are best managed by exploration and reconstruction, with nephrectomy reserved for life-threatening hemorrhage or kidneys injured beyond repair. The urologist as well as the emergency medicine physician may thus be required to participate in the care of a patient with a suspected renal injury and should be up to date on staging and imaging of suspected renal injuries, indications for operative intervention, and reconstructive techniques for the management of renal trauma. Ultimately, the objective of managing these patients is to prevent significant hemorrhage and retain enough functioning nephron mass to avoid end-stage kidney

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failure. A secondary goal is to avoid complications specifically attributable to the traumatized kidney.

This chapter reviews current recommendations for evaluating the patient with suspected renal trauma, highlighting the indications for exploration and the role of nonoperative management. Renovascular injuries as well as pediatric renal trauma are also highlighted. Finally, complications associated with operative and nonoperative management are discussed.

CLASSIFICATION AND INITIAL EVALUATION

Approximately 90% of renal injuries result from blunt trauma, usually falls from great heights, motor vehicle crashes, and violent assaults. Most of these injuries are minor and rarely require exploration. At San Francisco General Hospital, only 2% of all bluntly injured kidneys have required exploration or repair *(1)*. Pediatric kidneys as well as congenitally abnormal kidneys (cystic kidneys, hydronephrotic kidneys) are more susceptible to major injury secondary to blunt mechanisms *(2)*. Although only 10% of renal injuries result from penetrating trauma, up to 55% of these injuries will require exploration or repair. This is usually consequent to more severe renal injury, associated intraabdominal injuries, incomplete preoperative radiographic staging, or a combination of these factors *(3)*.

The American Association for the Surgery of Trauma (AAST) has created an organ injury scale for renal injuries; the scale correlates with patient outcomes and permits appropriate and selective management to be undertaken *(4)* (Fig. 1). This is one of the few classification trees prospectively validated and found to correlate directly with need for surgical intervention *(5)*. Grade I injuries include subcapsular hematomas and renal contusions. Grade II injuries involve small parenchymal lacerations into the renal cortex. Grade III parenchymal lacerations extend through the corticomedullary junction. Grade IV injuries involve violation of the collecting system and include vascular injuries such as main renal artery or vein injury with contained hemorrhage. Grade V injuries include kidneys with pedicle avulsion off the great vessels as well as completely shattered kidneys. This final category of injury is life threatening by definition.

Clinical staging begins with careful history and physical examination, including the determination of the presence of hematuria. Based on these criteria, a subset of patients likely to have significant renal injury may be identified. This subset may then undergo radiographic staging to stage the injury completely and determine whether operative management is indicated.

History should focus on the mechanism of trauma (blunt or penetrating), as well as presence of significant deceleration, which should raise suspicion for significant renal injury. In penetrating trauma, knowledge of type of bullet (high vs low velocity) or knife used in the assault may assist in prediction of degree of renal injury. On physical examination, the presence of shock (defined as systolic blood pressure [SBP] below 90 mmHg) should be recorded. The lowest recorded SBP is critical in determining the need for radiographic imaging in adult blunt renal trauma *(6)*.

A patient in shock who cannot be resuscitated may require urgent laparotomy, thus bypassing radiographic staging of suspected renal injury. This patient will require intraoperative staging (*see* "Indications for Surgical Exploration"). The abdomen, flank, and

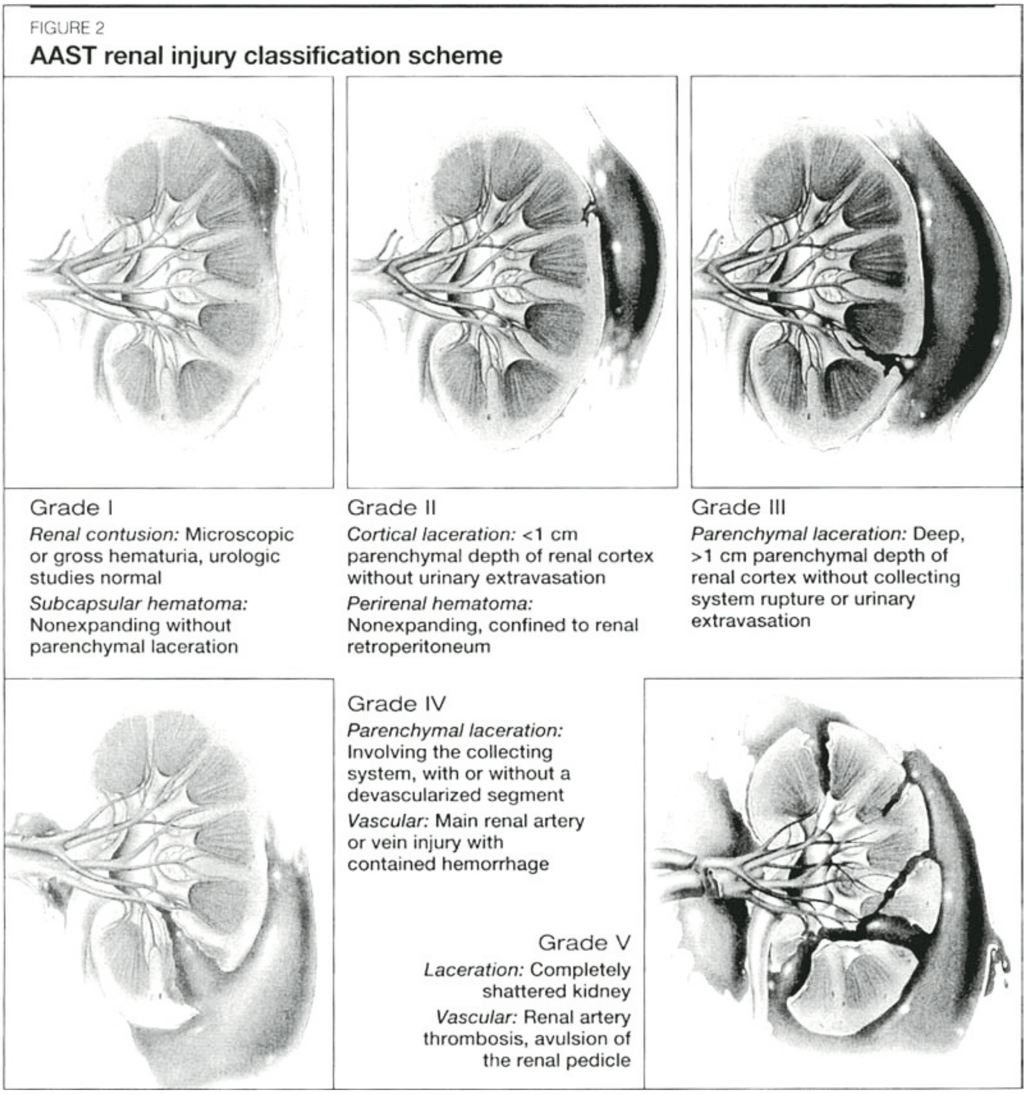

Fig. 1. American Association for the Surgery of Trauma classification of renal injuries. (From ref. *61*, p. 47.)

back should be carefully examined. Flank tenderness or ecchymosis as well as lower rib fractures may indicate underlying renal injury. In penetrating trauma, entry and exit wounds may point to a transrenal course.

Hematuria is the most common sign of penetrating and blunt renal trauma. However, the presence of hematuria does not correlate consistently with degree of renal injury *(7)*. This is particularly true in penetrating injuries, for which a high percentage of patients with significant renal injuries may have no hematuria. The first voided or catheterized specimen should be analyzed because hematuria may clear rapidly. Either dipstick or microscopic analysis may be performed.

RADIOGRAPHIC STAGING

Using the clinical information outlined above, the indications for radiographic imaging may be tailored to detect patients with a significant chance of having a major renal laceration (considered grades III–V). Based on our experience at San Francisco General Hospital, we recommend imaging patients *(8)* with the following categories of injuries:

1. Penetrating trauma: abdomen, flank or back injury with *any* degree of hematuria, particularly when the course of the missile appears to involve the kidney or ureter.
2. Blunt trauma with either gross hematuria or microhematuria associated with *shock* (defined as any recorded SBP below 90 mmHg.). Patients who sustain blunt trauma and have microhematuria without associated shock can safely avoid renal imaging *(9)*.
3. Blunt trauma in the setting of significant deceleration injury, such as falls from heights *(10)* or high-speed motor vehicle crashes. This mechanism of injury has been associated with a higher incidence of ureteropelvic junction disruption as well as renovascular trauma.
4. Pediatric penetrating injury or blunt trauma with microhematuria greater than 50 red blood cells per high-power field (RBC/HPF) *(11)*. There is mounting evidence that the adult imaging criteria outlined above will identify the majority of significant renal lacerations in children *(12)*, but this remains a controversial topic (*see* later). The clinician should continue to maintain a low threshold for renal imaging in the pediatric population.

Contrast-enhanced CT scanning has replaced intravenous pyelography (IVP) as the imaging modality of choice in renal trauma patients. CT is noninvasive and offers rapid and accurate detection of renal injuries as well as associated injuries to other organs *(13)*. CT defines depth and extent of lacerations, a functioning contralateral kidney, the presence of associated hematoma and contrast extravasation (suggesting collecting system violation), as well as any devitalized renal parenchyma (Fig. 2). Consideration must be given to each of these factors when deciding on a treatment plan.

Helical (spiral) CT scanning has been used because of its speed in the trauma setting. The patient may pass through the scanner in a few minutes. It has limited use in fully staging renal injuries because contrast may not have reached the renal calyces or renal pelvis before the images are procured. Significant collecting system injuries may thus be missed *(14)*. We routinely obtain a set of delayed images at 10 to 20 min to visualize the entire collecting system to the bladder. A plain radiograph (kidneys, ureter, bladder [KUB]) at this time may add complementary information to the CT scan. CT is also accurate in demonstrating renovascular injuries, when present. Renal artery occlusion as well as active bleeding may be accurately detected *(15)*.

CT findings consistent with main renal artery injury include lack of renal enhancement or abrupt cutoff of an enhancing artery (Fig. 3). Segmental arterial injuries typically appear as wedge-shaped infarcts with the apex facing the renal hilum *(1)*. Isolated main or segmental renal arterial thrombosis typically arises secondary to deceleration trauma, causing the disruption of the inelastic intimal layer with subsequent irreversible parenchymal ischemia and infarction. A renal vein laceration may be suspected by the finding of hematoma medial to the renal hilum, but similar findings may occur with lumbar vein injuries.

Adjunctive radiographic imaging techniques include renal ultrasound, nuclear scintigraphy, and magnetic resonance imaging, and retrograde pyelography. Ultrasound is readily available and noninvasive. Although it is an operator-dependent study, it will usually identify significant parenchymal lacerations *(16)*. It

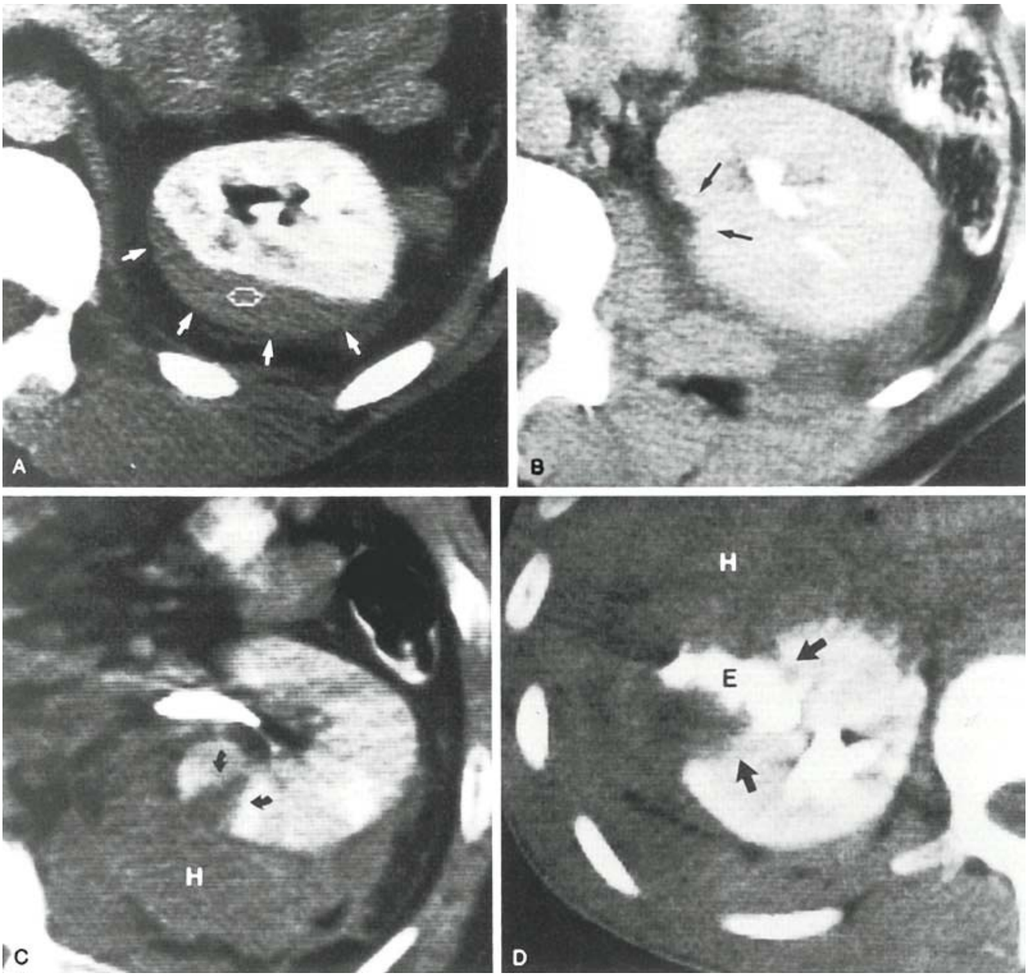

Fig. 2. The spatial resolution of computed tomography (CT) allows it to identify clearly the subcapsular hematoma **(A)** (arrows outline renal capsule) and differentiate superficial **(B)** from deep **(C)** lacerations, without **(C)** and with **(D)** extravasation of opacified urine (arrows identify laceration margins, and the letters H and E indicate perirenal hematoma and urinary extravasation, respectively. (From ref. *25*, p. 99.)

may be used to assess injuries to other associated organs. Ultrasound has limited ability to assess the renal vasculature, however. Doppler ultrasound may increase the sensitivity of this modality in detecting renal vascular injuries, but it appears to have no significant benefit over CT scan.

Renal nuclear scintigraphy has a limited role in the acute trauma setting. Although it provides accurate functional information with less radiation exposure (compared to CT or IVP), nuclear scans provide limited anatomic detail and are inferior to CT regarding regional anatomy. Nuclear scans are of value when following the function of a traumatized kidney following nonoperative or operative management *(17)*. None of these are recommended as first-line studies in the acute setting.

Arteriography is diagnostic of renovascular injury and may occasionally be used therapeutically (*see* later), specifically in cases requiring renal arterial embolization or

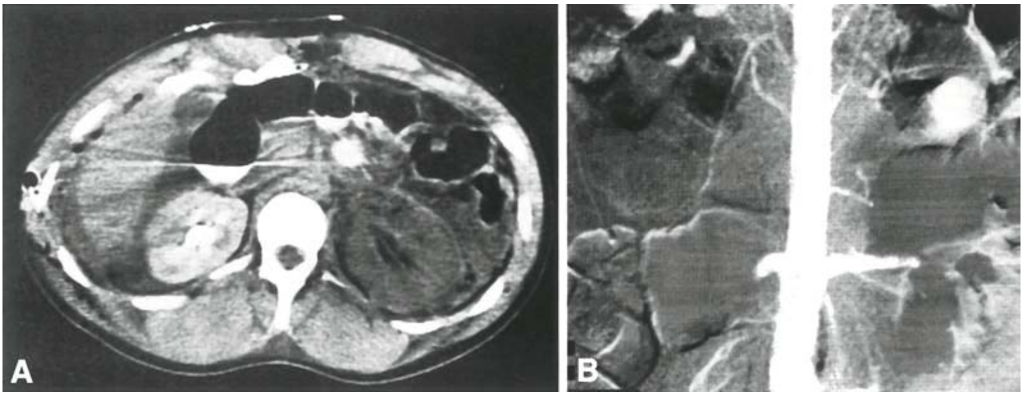

Fig. 3. Left renal arterial thrombosis secondary to blunt renal trauma. Note the intact renal contour with no parenchymal enhancement. (From ref. *62*, p. 122.)

stenting of a thrombosed renal artery. Patients with renovascular injuries have usually sustained other significant visceral injury requiring laparotomy and will only rarely be stable enough to undergo selective renal angiography.

INDICATIONS FOR SURGICAL EXPLORATION

The vast majority of renal injuries are contusions or minor lacerations and may thus be managed nonoperatively if adequately staged. Based on mechanism of injury, presence of hematuria, and radiographic staging, we have created and successfully employed an algorithmic approach to adult renal injuries (Fig. 4). Appropriate radiographic staging has also permitted selective nonoperative management of major lacerations in both blunt and penetrating trauma. In a recent series of grade IV lacerations at San Francisco General Hospital, 22% were successfully managed nonoperatively *(18)*.

Penetrating injuries more commonly require laparotomy because of associated injuries or hemodynamic instability. In our experience, however, 55% of stab wounds and 24% of gunshot wounds were successfully managed expectantly using careful selection and complete clinical and radiographic staging *(19)*. If expectant management is selected for a major renal laceration, close monitoring with serial hematocrit measurements and liberal use of repeat imaging are indicated. The expectant approach thus does *not* imply nonsurgical management, and the urologist must be prepared to intervene surgically when necessary.

The only absolute indication for surgical exploration in renal trauma is massive and potentially life-threatening hemorrhage from a severely injured kidney (grade V injuries) *(20)*. These patients often present in deep shock, and it is thus rare for them to have undergone radiographic staging prior to emergency celiotomy. The typical intraoperative finding of a pulsatile or expanding retroperitoneal hematoma usually signifies a major renal vascular or parenchymal injury, and exploration and reconstruction should be performed expeditiously. In the setting of renal pedicle avulsion or severely shattered kidney, reconstruction may be impossible, and nephrectomy may be lifesaving *(21)*. Some studies have attempted to manage grade V renal injuries in a nonoperative/expectant fashion *(22)*. On careful review, many of the kidneys so managed involved multiple deep lacerations without pedicle avulsion or a truly shattered kidney with massive bleeding. We believe that the grade V classification should be reserved for kidneys that require urgent operative intervention *(23)*.

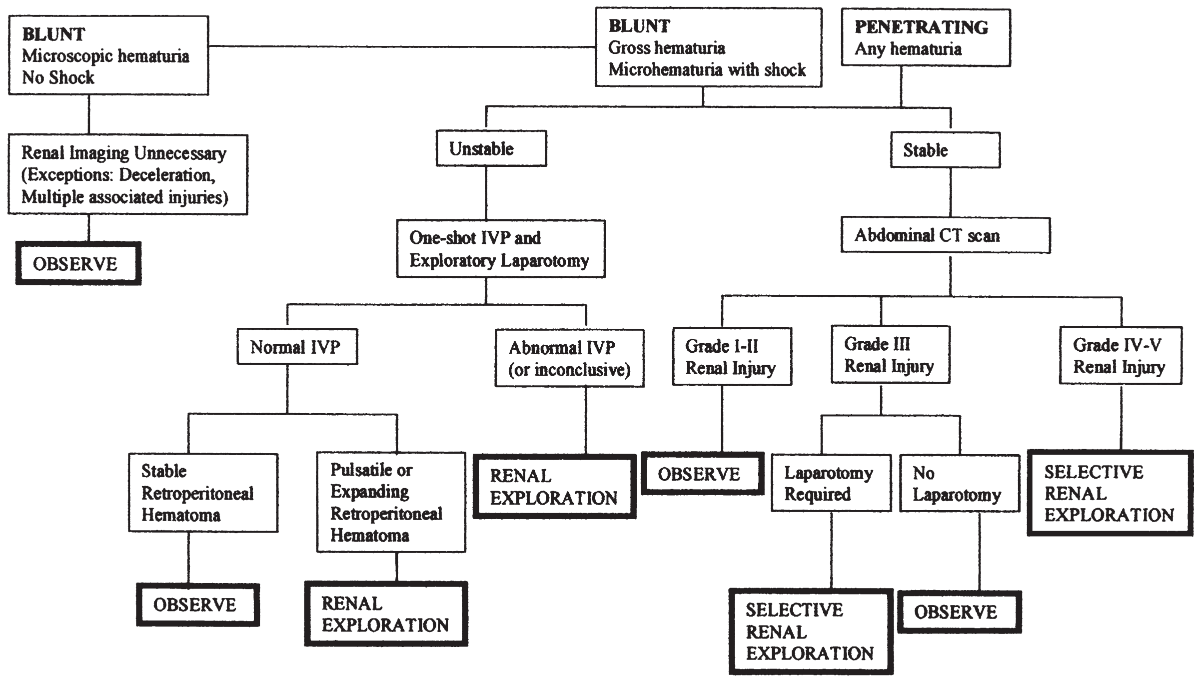

Fig. 4. Algorithm for patients with adult renal trauma. IVP, intravenous pyelogram. (From ref. *8*, p. 445.)

Relative indications for renal exploration include incomplete staging, devitalized renal parenchyma, vascular injury, and urinary extravasation *(24)*. In cases of the critically injured patient, complete preoperative radiographic staging is usually not possible prior to laparotomy. The urologist may also be called for an unexpected retroperitoneal hematoma found at the time of laparotomy in the trauma patient. An intraoperative "one-shot" high-dose IVP is an invaluable study in this setting *(25)*. A single abdominal plain film is obtained 10 min following the push injection of a 2-cc/kg bolus of intravenous contrast material. This film confirms the presence of a normally functioning contralateral kidney and helps stage the injury of the affected renal unit. Any abnormality on the intraoperative IVP should prompt renal exploration and repair.

In addition, all patients with penetrating trauma and incomplete preoperative staging and a retroperitoneal hematoma require exploration. Although the one-shot IVP may be indeterminate, a study found that it successfully obviated renal exploration in 32% of patients in whom it was required *(26)*. Furthermore, this approach has not been found to increase the rate of unnecessary nephrectomy *(1)*. The initial celiotomy is the optimal time for any required renal reconstruction. Delayed exploration has resulted in nephrectomy rates as high as 50% *(16)*.

Significant amounts of devitalized renal parenchyma are often best managed by early surgical debridement. Expectant management of patients with devitalized fragments and associated intraabdominal injury may lead to a higher rate of abscess and infected urinoma formation as well as delayed bleeding, all of which may require open surgical management *(27)*. Immediate exploration in this setting reduced the post-trauma complication rate from 82 to 23% *(28)*. This finding suggests that major renal lacerations with devitalized fragments and associated intraabdominal injuries should be immediately repaired, particularly if a laparotomy is already planned by the trauma surgeon. We also feel that patients with a major devitalized fragment associated with urinary extravasation and a significant hematoma are ultimately best treated by early exploration and reconstruction, even without concomitant intraperitoneal injury. However, the nonoperative approach in this situation may be more prudent for the urologist who rarely undertakes renal exploration in the trauma setting.

Urinary extravasation signifies collecting system violation secondary to a major renal laceration, but does not specifically mandate surgical repair. The collecting system may be violated at a fornix, a minor or major calyx, or most significantly, through the renal pelvis and ureteropelvic junction (UPJ). Although the majority of lacerations into fornices and minor calyces will seal spontaneously, larger degrees of extravasation may leak for a prolonged period and are less likely to resolve spontaneously *(29)*. Serial CT scans are mandatory in the management of these patients. The first scan should be obtained at approx 36–48 h postinjury to rule out the development of significant new complications *(30)*.

Intervention is indicated for sepsis, ongoing leakage, or significant urinoma formation. In these cases, placement of an indwelling ureteral (double J) stent may speed resolution of extravasation *(31)*. Lacerations of the renal pelvis usually do not resolve spontaneously and should be surgically repaired. Similarly, UPJ avulsion mandates surgical repair. These unusual injuries are more commonly found in deceleration injury of children. CT findings that suggest UPJ avulsion include nonvisualization of the ipsilateral ureter and medial extravasation of contrast material *(32)* (Fig. 5). The urologist should also maintain a low threshold for repair of an extravasating kidney associated with a gunshot wound. These are often associated with significant

Fig. 5. Abdominal computed tomographic (CT) scan of a patient who sustained bilateral uretero-pelvic junction injuries. (From ref. *63*, p. 173.)

devitalized parenchyma secondary to blast effect, particularly when a high-velocity missile has been used.

RENAL VASCULAR INJURIES

The estimated incidence of renal vascular injuries is variable, but typically involves approx 25% of all major renal injuries. Major injury to the main renal artery or vein usually requires operative management. Of reported cases of renal vascular injuries, 60% involve renal arterial injury, 30% involve renal venous injury, and 10% involve both *(33)*. The left renal artery is more prone to deceleration injury/thrombosis than the right. Physical examination is not usually specific for renal vascular injury, and gross hematuria may be absent in as many as 40% of cases *(34)*. These patients have higher rates of complications, renal loss, and mortality compared to those with nonvascular renal injuries *(35)*.

Despite the ongoing advances in trauma care, successful renal salvage after major renovascular injury only occurs in 25 to 35% of cases *(36)*. A recent multicenter review of outcomes following major renovascular trauma found that grade V injuries, blunt trauma, and attempted arterial repair all correlated with a poor result (renovascular hypertension, renal dysfunction) *(37)*. Time to reperfusion is the major factor in determining the ultimate outcome. Renal function is significantly impaired following 3 h of total and 6 h of partial ischemia. Despite a technically successful repair, late hypertension occurs frequently in these cases. It appears to complicate 50% of renal arterial injuries managed nonoperatively *(38)*, compared with 57% that were revascularized *(39)*. We thus reserve renal arterial repair for solitary kidneys, bilaterally injured kidneys, and in the rare situation of detection within 6 h of injury.

There have been encouraging early results in the use of endovascular techniques to place wall stents in select cases of renal artery thrombosis *(40)*, but long-term results have yet to be reported. In the uncommon young trauma patient without atherosclerotic disease, hemodynamic instability, or associated organ injury, this may be an attractive option for addressing isolated arterial thrombosis. Similarly, selective renal embolization may play an important role in obtaining hemostasis in major renal vascular injury, particularly if no other injuries are present. Subselective catheterization and embolization of the lacerated vessel may minimally compromise the remaining normal parenchyma *(41)*.

If detection of renal artery thrombosis is delayed and celiotomy is otherwise indicated, nephrectomy should be performed at that time. Otherwise, the kidney may be allowed to atrophy, with delayed nephrectomy performed if hypertension develops.

PEDIATRIC RENAL TRAUMA

The pediatric kidney is more susceptible to injury than the adult kidney. The pediatric kidney has less protective perinephric fat and occupies a larger portion of the retroperitoneum than does the adult kidney. There is also less protection from blunt trauma secondary to less-developed back and chest wall musculature. A child's kidney is also more mobile, and deceleration forces put significant shearing stress on the renal pedicle. Renal congenital anomalies (including UPJ obstruction, malrotation, and duplex collecting systems) appear to predispose the kidney to greater risk of injury *(42)*. Motor vehicle crashes and falls are the most common causes of renal trauma in the preadolescent age group, with penetrating trauma increasing in prevalence in the adolescent years.

The imaging criteria for children with suspected renal injuries are less well established. Because children may dramatically increase systemic vascular resistance, hypotension may not occur with a significant renal laceration *(43)*. Although some have argued that significant renal injuries may present without any hematuria *(44)*, it has been our experience that major renal injuries are unlikely in children with blunt injury without gross or microhematuria (>50 RBC/HPF) *(45)*. The history, clinical status, and mechanism of injury all play key roles in the decision to image a child with suspected renal trauma. CT scan with intravenous contrast and delayed images has become the study of choice in imaging pediatric renal trauma. As in the adult population, most lacerations are minor and will be successfully treated nonoperatively, with exploration reserved for major renal injuries or incomplete staging.

RENAL EXPLORATION AND RECONSTRUCTION

Proximal Vascular Control

Historically, renal exploration in the trauma setting usually resulted in total nephrectomy. Using a refined approach to proximal vascular control and a meticulous approach to reconstruction, we have successfully repaired 87% of kidneys requiring surgical exploration *(1)*. Our primary goals for reconstruction include control of renal hemorrhage, preservation of maximal parenchyma, and reduction of potential complications attributable to the injured kidney *(46)*.

The main indication for unplanned nephrectomy in the trauma setting is uncontrolled hemorrhage. We therefore routinely obtain proximal vascular control prior to opening

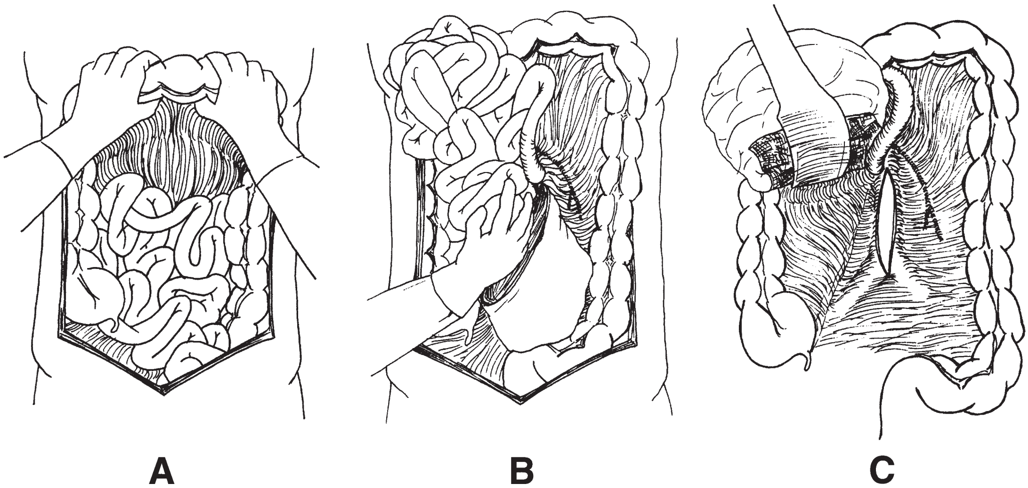

Fig. 6. Exposure for proximal vascular control in renal trauma. (From ref. *46*, pp. 32–33.)

the retroperitoneal hematoma *(47)*. Although temporary vascular occlusion is rarely necessary (approx 13% of our renal explorations), there is no accurate method of determining which kidneys will require this maneuver during the subsequent reconstruction. Those who have presented series suggesting pedicle control can be safely obtained if necessary following release of the perinephric hematoma have reported nephrectomy rates approximately three times higher than those recorded at San Francisco General Hospital *(48,49)*.

The traumatized kidney should be explored through a midline transperitoneal incision extending from the xiphoid process to the pubic symphysis. Except in cases of renal pedicle avulsion, all associated intraabdominal injuries (spleen, liver, pancreas, small and large intestines) should be addressed before renal exploration, thus allowing Gerota's fascia to maintain its natural tamponade effect on the hematoma.

The approach to the injured kidney begins with proximal vascular control. The transverse colon is wrapped in moist laparotomy sponges and placed on the chest (Fig. 6). The small intestine is placed in a bowel bag and retracted superiorly and to the right. This exposes the root of the mesentery, the ligament of Treitz, and the underlying great vessels. The retroperitoneal incision is made over the aorta superior to the inferior mesenteric artery and extending up to the ligament of Treitz. If a large retroperitoneal hematoma obviates easy palpation of the aorta at the level of the ligament of Treitz, the incision may be made medial to the inferior mesenteric vein. This vein is an important guide, located a few centimeters left of the aorta. It is easily identifiable, even in the presence of a large hematoma *(50)*.

Dissection should be carried superiorly along the anterior wall of the aorta until the left renal vein is identified crossing anterior to it (Fig. 7). This vessel is encircled (but *not* occluded) with a vessel loop, allowing it to be retracted cephalad. It serves as a guide to the remaining renal vessels, each of which is then encircled in vessel loops. These vessels are all left unoccluded unless heavy bleeding is encountered during the renal dissection. In our experience, most bleeding is successfully controlled with manual compression alone. Temporary renal vascular occlusion should be less than 30 min to minimize warm ischemic damage *(51)*.

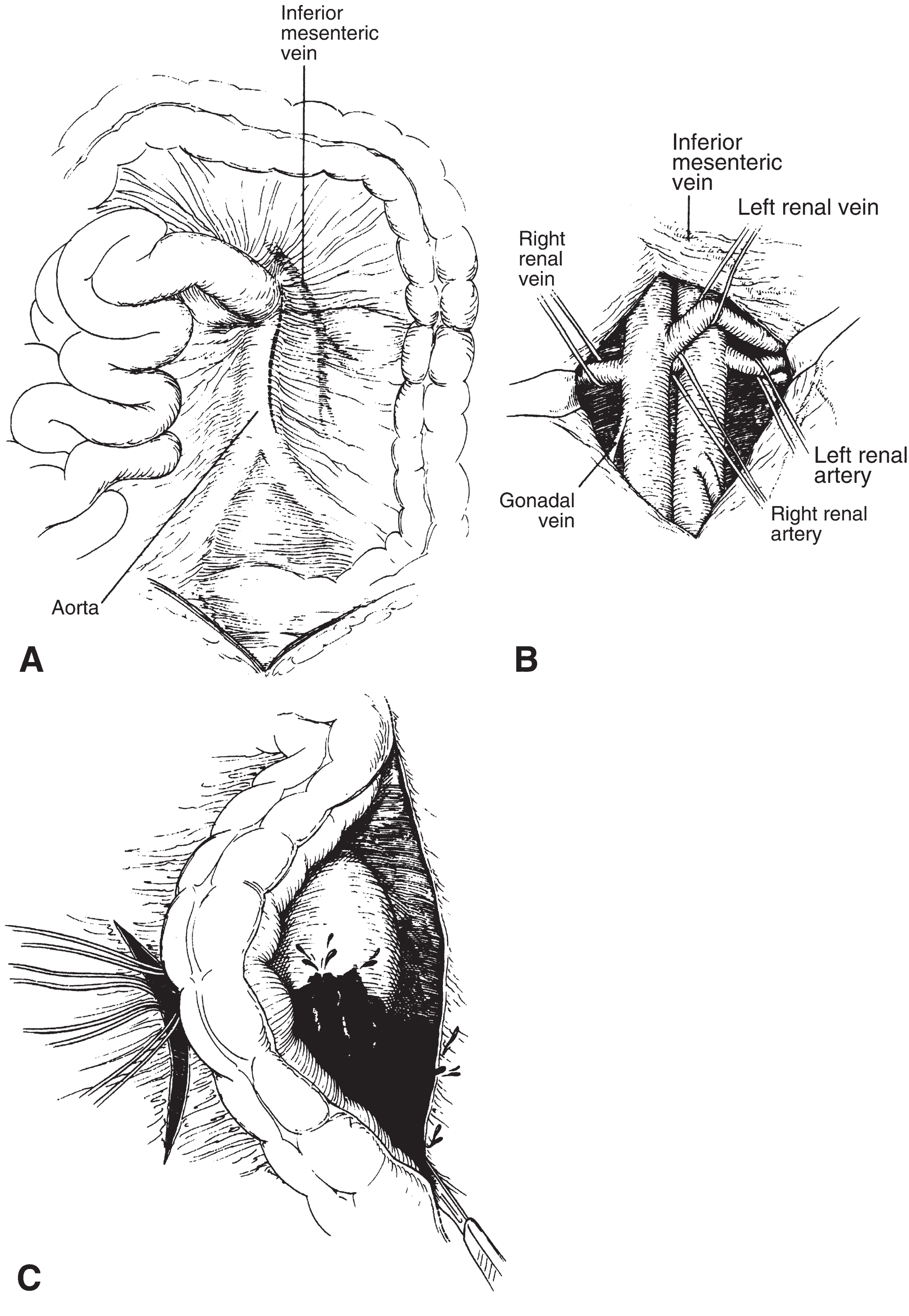

Fig. 7. The renal vasculature is approached medially after incising over the aorta. Note the anatomic relationships of the renal vessels. (From ref. *53*, p. 107.)

After vascular control has been successfully achieved, the injured kidney may be exposed by mobilizing the ipsilateral colon along the white line of Toldt and reflecting it medially. Gerota's fascia is then incised along the lateral aspect of the kidney to expose the kidney completely. Care should be taken to maintain the integrity of the renal capsule as the kidney is mobilized to decrease hemorrhage and preserve the capsule for later closure.

Principles of Reconstruction

The general principles applicable to all renal reconstructions include the following: (1) broad exposure of the entire kidney; (2) temporary vascular occlusion for bleeding not arrested by manual compression of the parenchyma; (3) sharp debridement of non-viable parenchyma; (4) meticulous hemostasis; (5) watertight collecting system closure; (6) primary reapproximation of the parenchymal edges (renorrhaphy) or coverage of the parenchymal defect; (7) omental interposition flap placement to separate reconstructed kidney from surrounding pancreatic, colonic, or vascular injuries; and (8) retroperitoneal drain placement *(52)*.

The kidney should be debrided sharply back to viable, bleeding parenchyma (Fig. 8). To avoid dialysis, 30% of one normally functioning kidney is required; this should serve as a guideline in determining whether renal salvage should be undertaken *(53)*. Major polar injuries are best managed with partial nephrectomy; lacerations to the midkidney should undergo renorrhaphy (*see* later). Hemostasis is then performed by individually suture-ligating arterial vessels with 4-0 chromic sutures. We then place hemostatic agents such as thrombin-soaked Gelfoam bolsters or Flo-Seal® between the cut parenchymal edges.

The collecting system is then inspected for obvious tears. Injection of 2–3 cc methylene blue into the renal pelvis (using a 27-gage needle) may demonstrate these openings more clearly. They are then oversewn with running 4-0 chromic suture. We place a double-J stent only in significant renal pelvis or ureteral injuries, but not in simple calyceal injuries *(54)*. In a deep, slitlike parenchymal laceration from a knife or sword, the thin parenchymal defect will not permit easy access to the collecting system, and we rely on closure of the overlying parenchyma to seal the collecting system *(9)*.

If the renal capsule is intact and viable, it should be used to close the parenchymal defect primarily without tension. If the capsule has been destroyed or the defect is too large to close primarily without causing ischemia, we routinely harvest an omental pedicle flap. The omentum is ideal for coverage because it imports its own vascular supply and lymphatic drainage, which will promote healing. Knowledge of omental anatomy and vasculature are critical to the dissection (Fig. 9).

Harvest begins by dissecting the greater omentum from its attachments to the transverse colon. If additional length is needed, the omentum may then be detached from the stomach and basing the flap on the right gastroepiploic artery. The omentum is guided through the paracolic gutter to reach the kidney and sutured to the defect with 3-0 absorbable sutures. If omentum is not available, the defect may be covered with perinephric fat or a peritoneal free graft; however, these are less-desirable options. For a shattered kidney or multiple deep lacerations, the kidney may be placed in an envelope of Vicrylmesh to stabilize the repair *(55)* (Fig. 10).

Following reconstruction involving the collecting system, a 1-in. Penrose drain is placed adjacent to the kidney and connected to a urostomy bag to drain any leak if necessary. Alternatively, a Jackson-Pratt (JP) drain may be used as long as it is *not* connected to suction, which would promote prolonged urinary drainage. These drains

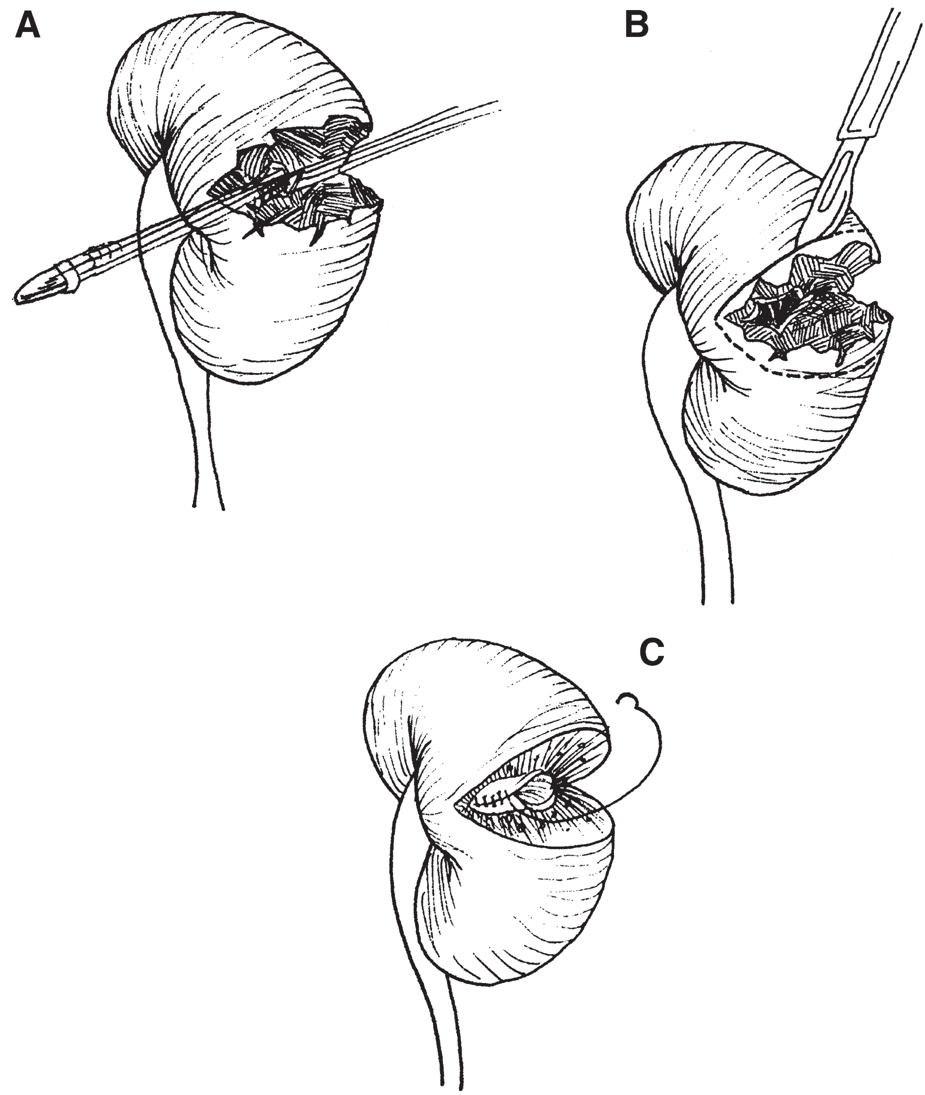

Fig. 8. Principles of renal reconstruction following a gunshot wound through the midpolar region. (From ref. *46*, p. 43.)

are typically removed after 48 to 72 h unless output is high, in which case the drainage creatinine should be measured. If the creatinine value suggests a urine leak, the drain is left in place for a more prolonged period. Placement of an indwelling ureteral stent may help expedite sealing of a persistent urine leak.

Specific Techniques

Renorrhaphy is appropriate for lacerations involving the interpolar aspect of the kidney (Fig. 11), or polar lacerations with a limited amount of devitalized tissue. This technique employs all the principles outlined in the preceding section. Following debridement and hemostasis, the collecting system is closed. The residual wedge-shaped defect is then closed over an absorbable thrombin-soaked Gelfoam bolster. Omental

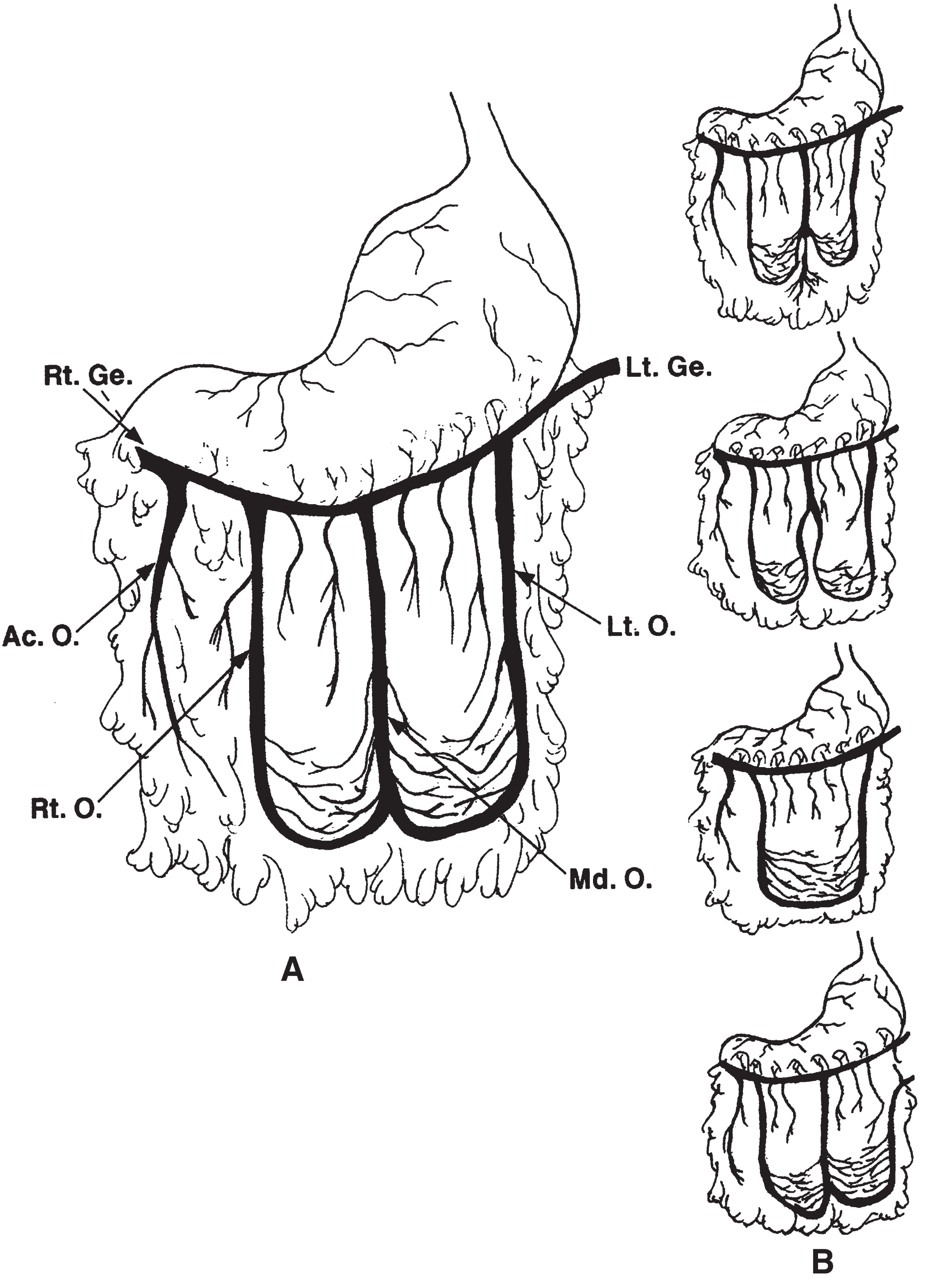

Fig. 9. Arterial blood supply of the greater omentum, key in mobilization of omental pedicle flaps. Rt. Ge., right gastroepiploic artery; Lt. Ge., left gastroepiploic artery; Rt. O., right omental artery; Lt. O., left omental artery; Md. O., middle omental artery; Ac. O., accessary omental artery. (From ref. *46*, p. 41.)

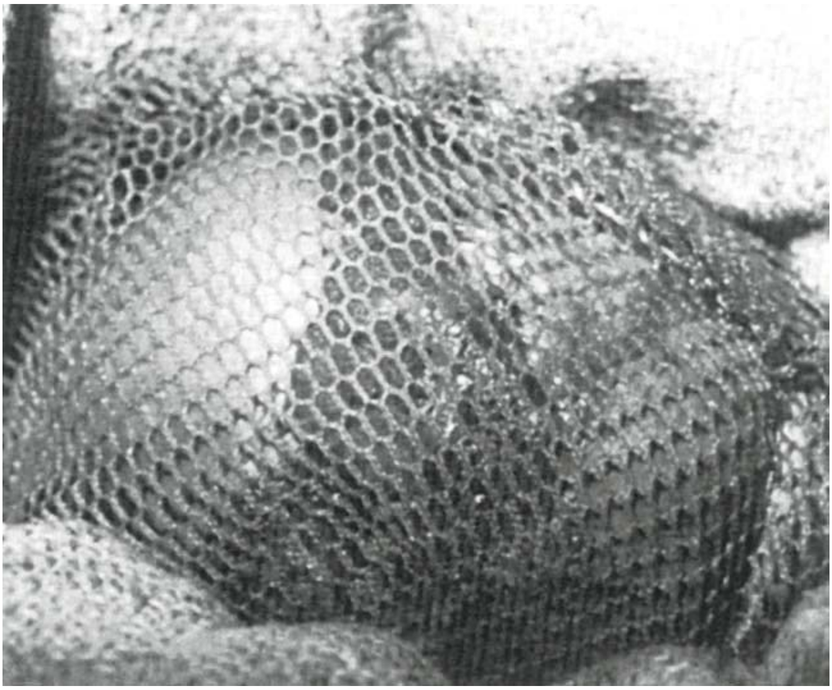

Fig. 10. Absorbable mesh placed around kidney serves as support for renorrhaphy. (From ref. *53*, p. 111.)

flaps are used for large parenchymal defects. To identify the site of the repair on subsequent imaging studies, we place small titanium surgical clips on the sutures that approximate the capsular edges.

Extensive damage to the upper or lower renal poles usually requires partial nephrectomy (Fig. 12). The capsule should be dissected off the fractured parenchyma for use in defect coverage. Following hemostasis and collecting system closure as outlined in the preceding section, the defect may be covered by capsule (if available) or by an omental pedicle flap.

VASCULAR INJURY AND REPAIR

Unlike parenchymal lacerations, renovascular injuries are frequently irreparable and may result in nephrectomy. Proximal vascular control is particularly critical in these cases. Injury to the main renal vein typically results in significant hemorrhage and may require ligation. If reconstruction is feasible, the partially lacerated vein may be repaired with 5-0 prolene suture following appropriate vascular clamping. Injuries to segmental veins may be safely ligated because of the extensive renal venous collateral circulation.

As mentioned, the ultimate outcome of attempted renal arterial reconstruction is time dependent. Segmental arterial injuries may be safely ligated, with few complications arising from the subsequently devascularized renal parenchyma *(56,57)*. Alternatively, a partially lacerated segmental artery may be repaired with 5-0 or 6-0 prolene suture.

In cases of main renal artery injury, the type of repair indicated relates to the extent and mechanism of injury *(58)*. Penetrating injuries with incomplete transection may be

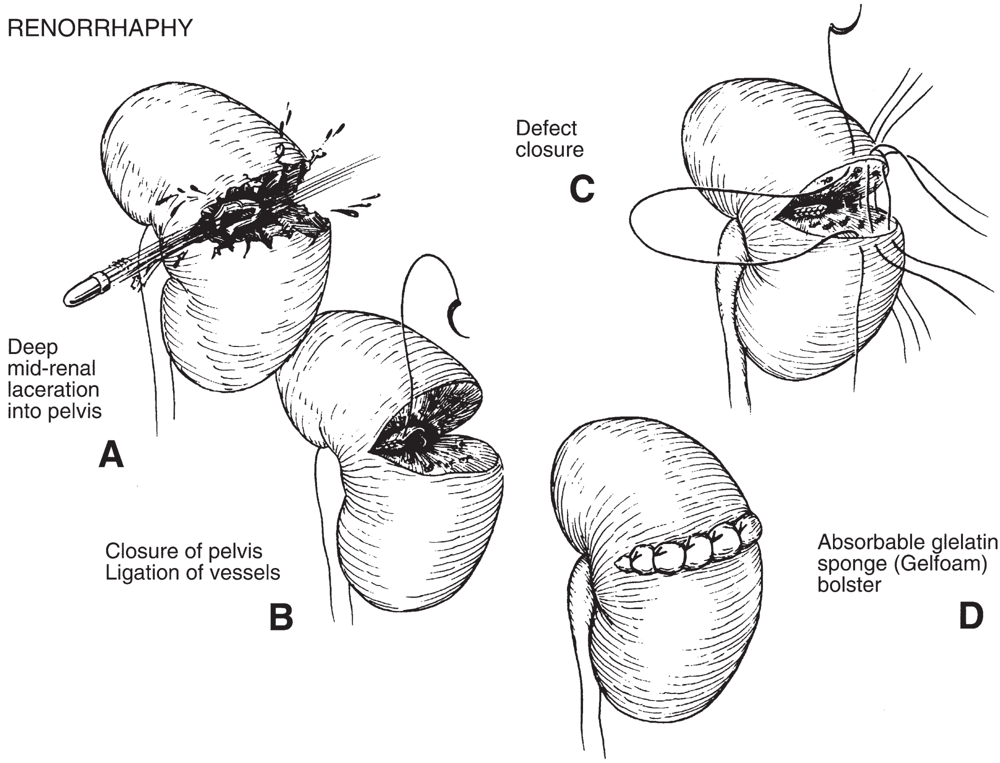

Fig. 11. Technique of renorrhaphy after midpolar penetrating injury into collecting system. (From ref. *4*, p. 447.)

primarily repaired using 5-0 prolene sutures. Blunt injuries typically require thrombectomy and debridement of the damaged arterial segment. Ideally, a primary tension-free reanastomosis of the injured artery should be undertaken. If this is not feasible, we recommend a hypogastric artery interposition vascular graft. Less-attractive graft alternatives include reversed saphenous vein, Dacron®, or other vascular prosthetic materials. Although technically feasible, ex vivo renal reconstruction and autotransplantation into the iliac fossa are rarely indicated in the critically injured patient with multiple associated injuries *(59)*.

POSTOPERATIVE CARE AND COMPLICATIONS

A urethral catheter should be maintained until the patient is hemodynamically stable and mobile enough to void. The patient should be kept on bed rest until gross hematuria clears. We recommend obtaining an abdominal CT scan and radionuclide renal scan at approx 3 mo to quantify the function of the injured/reconstructed kidney. In our series of traumatically injured and subsequently reconstructed kidneys, the average differential renal function was 39%, corresponding to two-thirds of one kidney.

The reported complication rate following renal injury ranges between 3 and 20% *(37)*. Complication rates increase proportionately with increasing grade of injury and appear to be higher in kidneys managed nonoperatively *(22)*. Our complication rate is approx 10%. Interestingly, our complication rate (attributable specifically to the kidney) for grade IV injuries was similar for nonoperative and operative management, 5 and 4%,

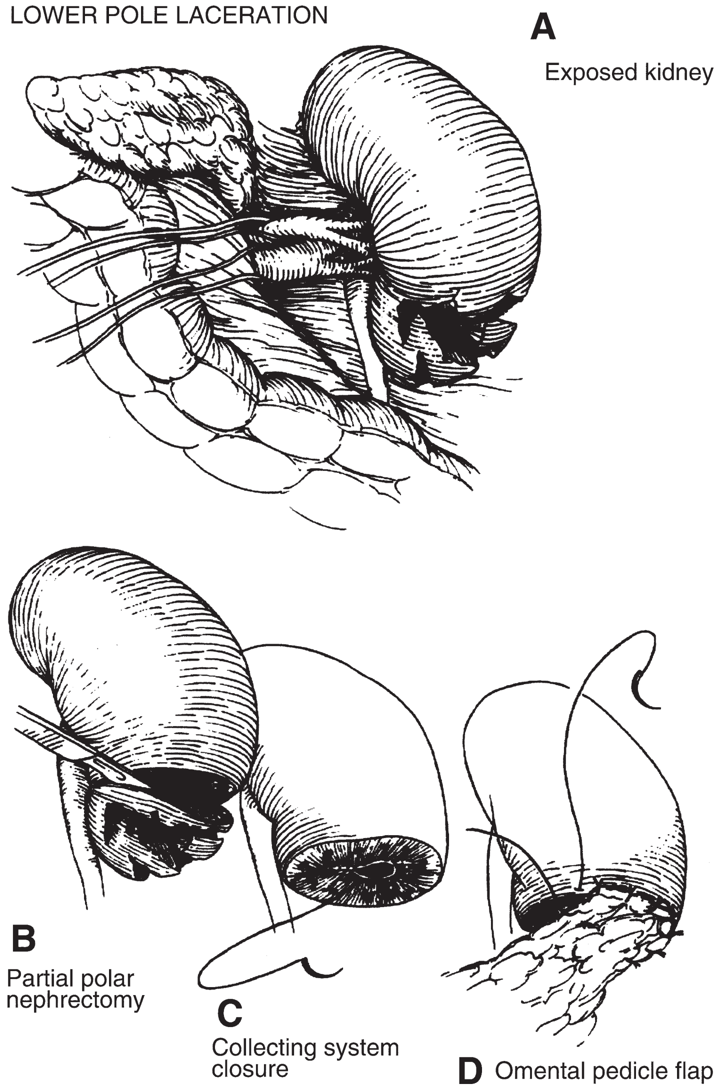

Fig. 12. Technique of partial nephrectomy following blunt trauma to the lower pole. Note complete debridement of devitalized parenchyma down to viable tissue, followed by hemostasis and collecting system closure. The defect may then be covered with capsule, Vicryl mesh, or an omental pedicle flap. (From ref. *53*, p. 108.)

respectively *(1)*. This is likely because of our higher rate of renal exploration (78% of grade IV injuries) than other series, as well as our patient selection for nonoperative management.

Complications may be divided into early (within 1 mo) and late complications. Early complications include urinomas, delayed bleeding, urinary fistulas, abscesses, and hypertension. Urinomas are the most common complication and are usually successfully managed by endoscopic stenting or percutaneous drainage. Delayed bleeding typically occurs within 1–2 wk of injury and is more commonly associated with stab wounds.