INTRODUCTION

From the critical care perspective, urologic surgical emergencies that may require urgent assessment and intervention include hemorrhagic, obstructive, infectious, ischemic, and traumatic processes, in addition to a wide variety of general urologic surgical and postoperative difficulties. Various oncologic emergencies also arise in urology and may require urgent critical care management. Urologic trauma—addressed in a separate section, below—encompasses a wide variety of injuries that may vary from immediately life-threatening issues to those requiring specialized reconstructive surgical capability, often impacting long-term functional outcomes. The ability to identify emergency urologic conditions for which time-sensitive action is needed is of paramount importance. A close, collaborative team effort between the urologic surgeon, the critical care specialist, and other specialty services, is important in the successful management of urologic emergencies.

PATHOPHYSIOLOGY

Gross Hematuria

This is an alarming symptom to both the patient and the medical practitioner, and may mandate immediate critical care intervention, depending on the magnitude of the hematuria and details of the individual case (1). Patients presenting with gross hematuria to the emergency department or in the hospital or postoperative setting may have a defined cause (e.g., diagnosed radiation cystitis, recurrent benign prostatic hypertrophy [BPH]-related bleeding, postoperative hemorrhage) or may represent a new sign not previously evaluated. In the posturologic surgery setting, troublesome gross hematuria may occur following transurethral surgery (prostate or bladder tumor resection) or following renal surgery. Immediate urologic intervention is necessary if the patient has clot retention, that is, unable to void or empty adequately due to the presence of clots in the bladder; is bleeding severely (which may be difficult to measure); has significant pain; is infected; has coagulopathy; or has other underlying medical factors leading to an increased risk of further complications. Vital sign measurement, physical examination, and basic laboratory studies including complete blood count (CBC), coagulation functions, electrolyte and renal function testing, urinalysis, and culture will often shed light on the above issues and determine the need for immediate intervention. Palpation and percussion of the bladder may reveal distention with or without tenderness; bladder ultrasound sound (BladderScan) or other readily available ultrasound instruments may rapidly answer the question of whether the bladder is distended. In the setting of gross hematuria and a distended bladder, drainage is needed and a catheter must be inserted. Often a small-caliber catheter is initially placed; this will not allow for adequate drainage or irrigation of clots. Clots must first be fully evacuated to allow proper catheter drainage as well as to determine the presence and degree of ongoing bleeding. Small clots may be evacuated via an 18- to 20-French catheter; large clots require a larger-bore catheter (22 to 24 French) for satisfactory evaluation. The catheter should be irrigated to and fro with a piston syringe using 60 to 120 mL of normal saline. When no further clot can be retrieved, the irrigation efflux should become clear if bleeding is not ongoing. If the efflux remains bloody despite complete clot evacuation, or if new clots continue to form, there is ongoing bleeding and input from the urologist is needed. One can change to a three-way catheter in the setting of continuing bleeding, and regulate the rate of saline inflow in order to keep the catheter patent, but this decision is best made along with urologic consultation. There are risks involved in the implementation of continuous bladder irrigation, including bladder rupture if the inflow of irrigant continues while the outflow lumen becomes occluded without recognition. It is desirable to seek early determination of the cause of troublesome gross hematuria, as definitive intervention via cystoscopic examination and fulguration may solve the problem with less morbidity and less blood replacement than more conservative approaches. Gross hematuria in the urologic postoperative setting will be addressed in more detail below.

Other hemorrhagic urologic problems requiring immediate critical care intervention include renal or perirenal bleeding (e.g., spontaneous hematoma in the anticoagulated patient or the renal tumor patient, surgical bleeding following intrarenal surgery) or scrotal hematoma. Bleeding in these sites is often trauma related (see below Penetrating and Blunt Trauma to the Genitourinary System).

Urosepsis

This process is another major concern in the urology patient. Sepsis arising from the urinary tract may present in a precipitous and potentially life-threatening manner, or may be indolent (2–5). It is essential to understand the precarious nature of the combination of infection and obstruction in producing a dangerous septic state. A common scenario is the patient presenting with an obstructing ureteral calculus. Typical symptoms of ureteral colic include flank pain—often radiating to the lower quadrant, and ipsilaterally to the genitalia with distal stones—irritative voiding symptoms (when the stone is distal in the intramural ureter), nausea, vomiting, or distention, due to ileus. These symptoms can be extremely distressing and require urgent medical attention, but the most critical emergency seen in such a setting occurs when these symptoms are accompanied by infection and sepsis. The combination of infection and obstruction of the urinary tract (upper or lower) is a veritable surgical emergency requiring immediate action. Severe sepsis and septic shock may unfold rapidly in such situations with a significant mortality rate, even in the otherwise
healthy host. We teach our residents that the sun should never set on an undrained, infected obstructed urinary tract.

Other infectious states requiring urgent critical care intervention include renal or perirenal abscess, scrotal abscess, acute epididymo-orchitis, and Fournier gangrene (see below).

**Obstruction of the Urinary Tract and Urinary Retention**

Obstruction may require critical care intervention, independent of the presence or absence of hematuria or infection, in order to avoid or limit acute renal injury and persistent functional damage to the bladder. Upper or lower tract obstruction can result in acute or chronic renal failure, mandating prompt drainage to control metabolic instability. Acute urinary retention with bladder distention is a miserable experience for the patient, and must be promptly relieved by introduction of a catheter into the bladder, preferably by a transurethral route, or alternatively by a suprapubic (SP) route if the urethra is impassable.

**Ischemic States**

These represent another form of pathology for which immediate intervention is essential (6, 7). The classic example in urology is that of testicular torsion; delayed diagnosis of torsion is a common cause of unnecessary testicular loss, as well as avoidable litigation. After 8 hours of torsion, the likelihood of testicular salvage decreases significantly. A high index of suspicion is necessary when addressing “the acute scrotum,” with accurate history and physical examination forming the core of this assessment, and diagnostic imaging—mainly scrotal ultrasound, occasionally computed tomography (CT) scanning when extension from an intra-abdominal process is suspected—as appropriate. When clinical suspicion of acute testicular torsion is high, surgical exploration should not be delayed if confirmatory imaging is not readily and rapidly available; the outcome with regard to testicular salvage is critically time sensitive. The occasional negative exploration or the finding of some other cause of the acute scrotum is appropriate, similar to the principles of exploration for the acute abdomen and for acute appendicitis. Naturally, proper patient education is important preoperatively in addressing the differential diagnosis and the possibility of finding a lesion, which might have been manageable without surgery, as well as the possibility of orchietectomy. The differential diagnosis of the acute scrotum includes incarcerated or strangulated inguinal hernia for which urgent surgical management is also critical. Physical and sonographic findings are usually diagnostic preoperatively.

Other ischemic states of critical care relevance in urology include the ischemic kidney due to atherosclerotic or embolic disease or pedicle injury from trauma. The kidney begins to undergo irreversible loss of function following approximately 30 minutes of warm ischemia time; thus, rapid action is necessary.

**Oncologic Emergencies**

In urology these often involve hemorrhagic, obstructive, and infectious problems due to the effects of the primary tumor. Other emergencies include neurologic compromise and pain management issues. Prostate cancer may preferentially metastasize to the skeletal system, and sudden neurologic compromise from spinal cord compression due to prostate cancer is occasionally seen. Sensory loss, paralysis, and loss of urinary, bowel, and sexual function may be manifestations of neurologic compromise from malignant involvement of the central nervous system. When observed, immediate neurosurgical consultation should be obtained to determine if corticosteroids, emergency radiation therapy, or decompressive laminectomy are indicated; in addition, the input of a medical oncologist is valuable. Commencing androgen blockade therapy emergently may be of great value when prostate cancer patients present with complications such as neurologic or urinary obstructive compromise. Intramuscular luteinizing hormone–releasing hormone (LH-RH) agonists such as leuprolide acetate may be started immediately; to prevent transient worsening from the androgen flare that accompanies the initiation of such regimens, an antiandrogen drug such as bicalutamide should be commenced simultaneously or prior to the LH-RH analog.

**POSTOPERATIVE MANAGEMENT**

Both major and minor urologic surgery may present critical care issues that require rapid and accurate assessment and intervention. While the postoperative considerations following major retroperitoneal or pelvic surgery will be familiar to the surgical critical care specialist, as they present challenges similar to those seen in general and vascular surgery, there are special considerations in urologic patients. Patients undergoing endoscopic urologic surgery and genital surgery may present with postoperative issues less familiar to the critical care team, and it is important to understand the anatomy and the issues that may require expeditious intervention. Currently, many urologic procedures that had traditionally been performed through open surgical approaches are now commonly being approached via laparoscopic, robotic, and other minimally invasive surgical (MIS) techniques, bringing with them their own set of postoperative challenges. We will address the more common and important types of urologic procedures with relevance to the critical care provider.

**Upper Abdominal Surgery**

In urology this usually involves extirpative procedures on the adrenal gland, kidney, or ureter and/or reconstructive procedures on these structures.

Patient position during surgery and selection of incision are relevant to the postoperative management. While the anterior midline incision is often favored by general surgeons for open abdominal and intraperitoneal procedures, urologists often prefer to operate through the flank or through other incisional approaches to the upper abdomen. Large renal tumors are often approached through a subcostal or thoracoabdominal incision, which may penetrate the chest through the bed of the 8th to 11th rib through a rib resection or intercostal technique. Smaller or lower pole tumors renal are commonly approached through a subcostal flank or anterior incision, which generally does not enter the thoracic cavity. Such incisions may be developed as extraperitoneal exposure or through a transperitoneal route. The critical care provider in these postoperative patients should know how the patient was positioned, what
kind of incision was made, and whether it was transabdominal and intra- or extraperitoneal. These details allow one to anticipate the types of problems that may arise postoperatively. In flank surgery, postoperative atelectasis may involve the lung positioned downward against the operating table, particularly when the operation is prolonged and the patient is large. Occasionally, a bar or complete lung atelectasis may be noted and may require bronchoscopic intervention. If a tube thoracostomy is placed following urologic surgery, the standard problems typical of the use of such tubes can occur, including air leak or postoperative intrathoracic bleeding. Excellent pulmonary toilet is critical following upper abdominal and flank urologic surgery and, ideally, should be initiated preoperatively, with patients being medically optimized and taught to use an incentive spirometer, and then being closely monitored for pulmonary difficulties with early intervention as indicated. Postoperative pain from flank surgery can be a major problem and may require expert pain management intervention, continuous epidural analgesic strategies, subcutaneous pain pumps, and patient-controlled intravenous analgesic. Appropriate pain control is also key to minimizing pulmonary complications by aiding respiratory and coughing efforts.

Following surgery that involves removal or manipulation of the adrenal gland, the possibility of an early postoperative hypoadrenal state should be considered, including the potential for Addisonian crisis. These entities may be unsuspected and may be missed or noted with a delay in diagnosis when assessing postoperative electrolyte and hemodynamic abnormalities and other nonspecific signs that may be consistent with acute adrenal dysfunction or deficiency. The critical care specialist should know if the adrenal was removed along with the kidney, some degree of postoperative acute tubular necrosis (ATN) and acute kidney injury (AKI) may still occur. Whether this is clinically noted, or even relevant, depends largely on the state of the contralateral gland; standard management principles for acute renal insufficiency are applicable.

Acute renal insufficiency may occur following any major surgery, and is of particular concern following renal surgery. Partial nephrectomies may be performed using warm or cold ischemia techniques, and through open, laparoscopic, or robotic techniques. While the objective in such surgery is to minimize the negative impact on the function of the operated kidney, some degree of postoperative acute tubular necrosis (ATN) and acute kidney injury (AKI) may still occur. Whether this is clinically noted, or even relevant, depends largely on the state of the contralateral kidney; standard management principles for acute renal insufficiency are applicable.

Postoperative bleeding following renal surgery may be manifested by gross hematuria; hemodynamic instability; acute anemia; physical findings such as palpable flank hematoma or ecchymosis; or radiologic findings of blood in the renal fossa, chest (after a transthoracic procedure), or peritoneal cavity (after a transperitoneal procedure). If a drain is left in place following surgery, elevated output of bloody fluid is important to monitor. Following a partial nephrectomy, significant postoperative bleeding most commonly arises from arterial branch vessels within the renal parenchyma at the resection site. An effort is made intraoperatively to suture significant parenchymal bleeding points, whether the surgery is performed through open surgical or a MIS approach, often supplemented by the use of additional hemostatic agents, and coagulation instruments. If significant bleeding occurs following renal surgery, expectant management with transfusion and correction of any coagulopathy, return to the operating room (OR) for reexploration, angiographic embolization, or CT scanning—to assess the specific anatomic site of bleeding and judge the size of the hematoma—are options to consider. The choice between these measures is individualized based on the severity of the bleeding, patient condition and physiologic reserve, and access to imaging, interventional radiologic, and surgical resources. If there is evidence of major, early postoperative bleeding, rapid surgical reexploration is the best approach. If bleeding occurs in a delayed fashion and renal parenchymal bleeding is suspected, interventional radiology (IR) is usually favored. The patient should be maintained in a fluid-resuscitated state when a renal bleeding issue is evolving, with the hemoglobin at a level that would allow the patient to tolerate continued blood loss without catastrophic decompenation.

Urinary extravasation following upper urinary tract surgery may be manifested by increased drainage from suction drains, for which creatinine determination confirms the fluid’s identity as urine. Alternatively, urinary extravasation may present as intra-abdominal sepsis or with a mass effect from urinoma formation. Urologic input should be sought as to whether the region is well drained, whether the leak is expected, and whether intervention versus observation is indicated.

Pelvic Surgery

These procedures, frequently requiring postoperative critical care support, include exenterative interventions for malignancies (radical prostatectomy or cystectomy), simple open prostatectomy for benign prostatic hyperplasia, and reconstructive pelvic or perineal surgeries for obstruction or incontinence. Critical care issues typically relate to standard postoperative abdominal surgical concerns such as pain, bleeding, and ileus. Specifically with pelvic urologic procedures, management of tubes and drains, and recognizing when urinary extravasation arising in the postoperative period requires urgent attention, or can be managed expectantly, is important. Patients that have undergone major surgery involving an open bladder (open prostatectomy, bladder stone removal, etc.) may have significant bladder spasm postoperatively, requiring antispasmodic or anticholinergic medication. Bleeding following major urologic pelvic surgery may result in Foley (indwelling urinary bladder catheter [IUBC]) catheter occlusion with clot; it should be established with the urologist how much hematuria is acceptable and what measures should be taken if failure of IUBC drainage develops. Catheter manipulation should be pursued only with the input of the urologist, as aggressive IUBC irrigation after lower urinary tract surgery may damage the surgical closure or reconstruction site. Significant bleeding from the IUBC is relatively uncommon following radical prostatectomy, while dramatic hematuria is much more common following an open simple prostatectomy performed for BPH, in which the adenoma is enucleated from the prostatic capsule by finger dissection, leaving a raw, vascular tissue bed; urologic input is needed for problematic bleeding in such patients.

The possibility of anastomotic leakage or a missed injury to the ureter exists in the pelvic surgical patient. If inordinately high pelvic suction drainage is noted, the fluid should be sent for creatinine level to determine if a urine leak is present. If well drained, no immediate intervention may be necessary, but radiographic studies may be indicated to localize the site of extravasation and plan definitive management.
Following radical cystectomy for bladder cancer, complications may include urinary extravasation from the urinary diversion reconstruction, pelvic bleeding, ileus, bowel obstruction or anastomotic leak, and pelvic lymphocele. Cystectomy patients invariably require initial stays in the intensive care unit (ICU) postoperatively, due to the length and complexity of the surgery, potential for postoperative bleeding, and general comorbidity management. Patients undergoing major urologic surgery, and especially patients undergoing cystectomy and urinary diversion, may require nutritional support. These patients, who have had both a major exenterative procedure as well as complex bowel surgery, may have a prolonged ileus, develop partial small bowel obstruction, and be depressed, often requiring aggressive nutritional supplementation, which should be initiated early when a prolonged recovery is anticipated, to avoid the healing problems seen with development of a progressive catabolic state.

Deep venous thrombosis (DVT) and pulmonary embolism (PE) are risks of many urologic surgical procedures, and urologists are acutely aware of the issues related to DVT prophylaxis. Practice guidelines have been developed to support DVT prophylaxis and treatment decision making in urologic surgery (8). Because major retroperitoneal or pelvic surgery also presents significant risks for postoperative bleeding, a judicious approach to postoperative anticoagulation is applied, with careful assessment of DVT risk factors and risk–benefit analysis. Radical cystectomy is the procedure with the greatest DVT risk of the urologic operations, as an extensive pelvic lymphadenectomy is typically included, and many urologic oncologists will start medical prophylaxis regimens prior to, or early following surgery if there are no bleeding issues.

Other pelvic surgical procedures the intensivist may encounter include the wide range of pelvic floor reconstructive operations performed for management of prolapse or stress incontinence, as well as reconstructive procedures for obstructive lower urinary tract entities. The traditional pubovaginal sling or retropubic bladder neck suspension procedures, and particularly some of the newer procedures that involve passage of artificial tape and mesh materials either via the retro pubic space, through a transobturator foramen approach, or through other transvaginal techniques, may introduce risk of enteric pelvic injury or major pelvic vascular or nerve injury. If major bleeding occurs following these types of procedures, either via the surgical incisions or resulting in large pelvic hematoma and hemodynamic instability, pelvic exploration or angiographic study and control may be indicated, and vascular surgical expertise may be necessary.

Endoscopic Upper and Lower Urinary Tract Surgery

This encompasses a wide variety of commonly performed procedures, including diagnostic cystoscopy (rigid or flexible), cystoscopic surgery (bladder biopsy, transurethral resection of prostate or bladder tumor [TURP, TURBT]), ureteroscopy (rigid or flexible, diagnostic alone, or with stone manipulation or biopsy/fulguration), and percutaneous renal access surgery (percutaneous nephrolithotripsy [PCNL]). Each of these forms of urologic instrumentation can be simple or complicated, and may present challenges for the critical care provider (9–11).

Lower tract endoscopy for diagnostic purposes is usually performed in an office setting, typically using a flexible cystoscope; lidocaine jelly is usually used as a local anesthetic, typically instilled with a prepackaged applicator (Uro-Jet). While the procedure causes minimal discomfort, postprocedure infection can occur, but the risk is small if the urine is sterile or bacteriuria is appropriately treated preprocedure. Prophylactic oral or IV antibiotics are often administered for endourologic procedures to minimize the infection risk, but it is important to appreciate that the potential for postprocedural urinary infection and urosepsis cannot be entirely eliminated, even with judicious use of antibiotics. Gross hematuria can occur following even simple diagnostic cystoscopy, but is usually self-limiting and minimal. More involved cystoscopic surgery, on the other hand, is generally performed under regional or general anesthesia, and specific potential postoperative problems may occur following such procedures.

When endoscopic cutting or resection is required, a resector is used which is a rigid instrument employing a cutting loop or blade. Until recently, the most common irrigant used for TURP in the United States was 1.5% glycine, which is nonelectrolyte and isotonic to plasma. This irrigant would allow the electroresection system to function properly while avoiding hemolysis if intravascular extravasation occurs, a problem seen historically when sterile water was used as the irrigant. Cystoscopic surgery using glycine irrigation may result in significant hyponatremia if major absorption occurs, either directly into the vasculature (as with cutting into a periprostatic venous sinus during a TURP) or into interstitial tissues (as with fluid entering the retropubic space or infiltrating under the bladder trigone). If hyponatremia develops, one may observe altered mental status, bradycardia, hypertension, and respiratory compromise. Severe hyponatremia may result in cerebral edema and seizures. If this problem occurs and is recognized intraoperatively, the procedure is prematurely terminated. Diuretics with normal saline or hypertonic saline administered intravenously may be indicated, depending on the clinical manifestations. In most centers, the use of glycine irrigation and monopolar resection systems has now been replaced with bipolar systems that utilize normal saline irrigation, largely eliminating the problems seen with glycine irrigation. It is, however, important for the intensivist to understand the issues with the use of nonsaline irrigants, as such systems remain in use in some regions. In general, sterile water is avoided as an irrigant for extensive operative cystoscopy, confining its use to simple diagnostic cystoscopy.

If bladder perforation occurs during TURBT or bladder biopsy procedures, there is the potential for significant irritant extravasation to occur rapidly. If extraperitoneal, management with catheter drainage will suffice and the fluid is usually reabsorbed without sequelae unless the volume is very large, in which case placing a drain in the retropubic space to evacuate the fluid may be indicated. Minimal intraperitoneal resectoscopic injuries may be manageable with catheter drainage alone. If problems arise—such as abdominal distention, persistent extravasation—with this nonoperative approach to intraperitoneal bladder perforation, laparoscopic or open surgical repair should be performed. This situation is, of course, very different from the intraperitoneal bladder rupture due to blunt trauma, which typically results in a large defect in the bladder dome, consistently requiring suture repair to prevent urinary ascites and sepsis.

Blending may be a problem following either TURP or TURBT. Urologists are well trained to deal with this problem.
and distinguish arterial bleeding, which will likely warrant return to the OR for a second look and fulguration attempt, from acceptable venous bleeding, which is self-limiting. Often, continuous bladder irrigation via a three-way catheter is employed in the postoperative period to maintain catheter patency and prevent clot formation. While these devices are valuable adjuncts in our management of such patients, they introduce the potential for postoperative difficulties with occlusion of the outflow channel from clot, while irrigant inflow continues, as discussed above; bladder distention and bladder rupture can result in this situation. When managing any continuous bladder irrigation system, the intensivist must closely monitor the inflow and output, and palpate the lower abdomen on a regular basis to be certain that catheter occlusion with bladder distention does not occur. If uncertain as to whether the three-way catheter is draining properly, the inflow should be turned off while the catheter is irrigated or urologic assistance is obtained. Only normal saline should be used as irrigant for continuous bladder irrigation systems. For TURP procedures, maintaining gentle catheter traction may help control bleeding from within the prostatic fossa; only the urologist should implement or adjust the traction system. For TURBT procedures, catheter traction is of no value, as most bladder wall bleeding cannot be compressed with traction on the catheter balloon; a lower threshold to take the patient back to surgery for a second look is safer for troublesome post-TURBT bleeding. If a catheter needs to be changed in the early postoperative period following a TURP or TURBT, it is best done by the operating urologist’s team or on their specific order, as catheter reinsertion may be challenging or require a particular type of catheter or technique. In addition to the advent of the saline-based bipolar resection systems, other newer technologies for TURP and TURBT employing laser energy to ablate, vaporize, or coagulate tissue endoscopically, have gained popularity; these approaches usually result in less bleeding than the traditional electroresection approaches. Complications may relate to obstruction following catheter removal or to iatrogenic injury from misdirection of the laser energy.

Upper tract endoscopy—ureteroscopy, percutaneous nephroscopy—has progressed greatly in recent years, with the current instrumentation usually allowing complex upper tract procedures to be performed with low morbidity. Ureteroscopy is often performed for hematuria evaluation, treatment of ureteral or renal stones, endoscopic assessment, and treatment of upper tract urothelial neoplasms, and for addressing obstructive lesions with laser or other incision procedures. Normal saline is used for most such procedures, although glycine or sterile water may be needed when electrofulguration in the upper tract is planned. Problems that the intensivist may encounter usually relate to ureteral perforation, gross hematuria with stent occlusion or “clot colic,” obstructive problems related to retained stone fragments, or postoperative urinary infection or urosepsis. Percutaneous renal surgery may be accompanied by problems related to prone-position surgery, a high percutaneous access site traversing or affecting the lower chest, postoperative bleeding, or infection. Percutaneous nephrostolithotomy or nephrolithotomy involves gaining access to the collecting system through the flank with the patient in the prone position. A needle, guidewire, and balloon or other dilating system is utilized to place a hollow plastic working sheath through the flank and renal parenchyma into the collecting system, through which a flexible or rigid working nephroscope can be advanced. Laser, electrohydraulic, ultrasonic, or pneumatic devices are used to fragment and remove stones, or resection, incision, or fulguration instruments can be introduced to deal with neoplastic or obstructive lesions. Depending on the task to be accomplished, the access for percutaneous renal surgery may be obtained by the interventional radiologist or by the urologist. If entry into the upper pole calyx is needed for stone access, a supracostal puncture, above the 12th rib, may be required. Traversing the chest, the risk exists that a pneumothorax or hydrothorax may result, requiring tube thoracostomy postoperatively. If elevated airway pressures and difficulty with ventilation occur intraoperatively, these possibilities should be entertained and managed acutely. As the kidney is a highly vascular organ and the access traverses the renal parenchyma, significant bleeding can occur intraoperatively, perioperatively, or even days or weeks postoperatively at the time of nephrostomy removal. Occasionally, angiographic embolization may be necessary for major renal bleeding associated with PCNL. If brisk bleeding with hemodynamic instability occurs via an indwelling nephrostomy tube, the tube can be clamped while urologic input is urgently obtained. When removing a nephrostomy tube following PCNL, it is desirable to have a balloon tamponade catheter immediately available to place into the tract and inflate if significant bleeding ensues following tube removal.

For stone management, an alternative to endoscopic surgery that the intensivist may encounter is extracorporeal shock wave lithotripsy (ESWL). This approach involves the noninvasive fragmentation of renal or ureteral calculi with a shock wave generator system under fluoroscopic or ultrasound guidance. The procedure commonly produces transient gross hematuria, which is rarely troublesome, as ESWL does result in some mild blunt trauma to the kidney. The typical procedure involves focally administering approximately 3,000 shocks to the stone(s). Following ESWL, colic can occur due to obstruction from passage of fragments. Whether manageable expectantly with hydration and analgesics, or requiring stent insertion, depends on the stone burden, the amount of debris created, the size of residual fragments, the degree of symptoms, and whether there are signs of infection with obstruction.

Laparoscopy and Robotic Surgery

In urologic surgery in recent years, these techniques have become common and are now a major—if not the primary—modality for a wide range of surgical tasks that were previously performed solely through major open approaches. In many centers, the open radical retropubic prostatectomy (RRP) has been nearly replaced by the robotic-assisted laparoscopic prostatectomy (RALP), and kidney surgery done through a flank incision has been largely replaced by laparoscopic/robotic approaches, both for partial and total nephrectomy. The same special considerations that are relevant to all laparoscopic surgeries are important to urologic laparoscopy. Such common issues include postoperative ileus, CO2 retention, venous CO2 embolism, postoperative bleeding, unrecognized intraoperative iatrogenic injury, and trochar and port-site complications (12).

In laparoscopy for renal surgery, there are two potential major sites of postoperative bleeding: the renal pedicle and the renal parenchyma, the latter relevant for partial nephrectomy. The traditional means of controlling vessels in open surgery, using suturing and ligation, is often replaced in laparoscopic...
surgery with vascular stapling devices and instruments like the harmonic scalpel. The technology has advanced rapidly with these tools, and they are generally reliable and secure. There are, however, user-dependent factors and a learning curve involved in mastering the use of these devices. Bleeding can occur intraoperatively, immediately postoperatively or in a more delayed fashion, and manifest by hemodynamic and laboratory changes, or visible bleeding from instrument ports or incisions. When precipitous and life threatening, a quick return to the OR with either laparoscopic or open reexploration or, if rapidly available, angiographic control may be the most appropriate course. When less emergent and when the luxury of “further evaluation” is appropriate, postoperative CT scanning to determine if there is a renal or perirenal hematoma may be appropriate prior to a surgical intervention. If bleeding occurs from the cut surface of the kidney following either open or laparoscopic partial nephrectomy, angiography with subselective embolization is often the preferred approach.

Drains left within the abdomen, at the anticipated site of blood or urine drainage, following laparoscopic procedures are often placed intraperitoneally, as opposed to the case in extraperitoneal flank surgery, where the drain is often not within the peritoneal cavity. As such, intraperitoneal drains may at times evacuate retained irrigant, peritoneal or lymphatic fluid in variable amounts following surgery. If there is uncertainty as to the significance of increased drain output, fluid may be sent for chemical analysis: creatinine to determine if fluid is urine, amylase to rule out pancreatic fluid leak. Leakage of urine following laparoscopic urologic surgery may not require immediate intervention if the leak is well drained. If action is needed, postoperative ureteral stent insertion, along with an IUBC for optimal drainage or in some cases nephrostomy insertion, will often allow the collecting system to heal without sequelae. In general, drains should be removed as early as possible, as they may potentially allow the entry of bacteria into the abdominal cavity.

In the course of dissection during laparoscopic or robotic urologic surgery, especially if electrocautery is extensively utilized, the risk of unrecognized bowel or other visceral injury must be appreciated. The presentation of such complications may be subtle, with low-grade fever; minimal diffuse tenderness, which may be consistent with the expected postsurgical state; or delayed return of bowel function or persistent anorexia. A high degree of suspicion is important when patients fail to thrive following laparoscopic surgery, and postoperative CT scanning may demonstrate a fluid collection in an unexpected location or inflammatory changes in or near the intestine that would not be otherwise anticipated.

As robotic surgery for radical prostatectomy has now become standard and commonplace, the intensivist may encounter such patients in the postoperative period. The same considerations noted above apply to the RALP patient with regard to suspecting and identifying inadvertent injuries. Gross hematuria causing catheter occlusion is important to recognize, as the vesicourethral anastomosis in these patients is quite delicate and usually performed with a running suture. Clot retention from catheter occlusion can result in bladder distention, which may strain, or cause dehiscence of, the anastomosis. Clear instructions from the urologist should be noted regarding catheter management, what to expect regarding volume and appearance of efflux, and appropriate interventions. If a catheter fails to drain following RALP, cautious irrigation with normal saline is generally safe, using no more than 60 mL. If a small clot is present and this maneuver results in normal clear efflux, no further action is necessary. Otherwise, the urologist should be informed and should provide specific intervention instructions or deal with the situation personally. Under no circumstances should anyone but the operating urologist remove and/or attempt replacement of an IUBC during the early perioperative period following major lower tract urologic surgery, especially when a fresh anastomosis or reconstructive site is present such as post-RALP for after cystectomy with orthotopic urinary diversion; such manipulation without direct visualization may disrupt the reconstruction site and cause major additional complications.

Genital Surgery

Issues that may arise with these procedures, in the ICU, relate to urologic prosthetic devices such as penile, artificial sphincter, testicular prostheses; neurologic stimulator implants; or complications of the wide range of other genital and perineal procedures urologists perform. Dressings on the genitalia should be inspected for bleeding or excessive tightness, which can cause vascular compromise, especially if applied circumferentially around the penis. Paraphimosis, persistently retracted foreskin, must be promptly recognized and corrected. Any major local complaint by a patient following genital surgery should be referred to the urologic surgeon for input. It is important for the intensivist to know that a genitourinary prosthesis has been implanted. Obviously, there should never be any needle placement or incisional procedure performed by a nonurologist in the region of the genitalia in the setting of a prosthetic implant, as the fluid-filled components are prone to damage. If a patient with an artificial urinary sphincter (AUS) device needs an IUBC inserted, it is important that the device be deactivated (i.e., cycled and appropriately locked in an open position with the urethral cuff deflated). Forcibly passing a Foley catheter into the urethra of an AUS patient risks damage to the urethra and erosion of the device. Infection and erosion can occur with any of the urologic prostheses, occasionally resulting in abscess formation and/or major soft tissue infections and, potentially, sepsis; explantation and drainage procedures may be necessary, which require urologic surgical expertise. If uncertain as to how to approach any genitourinary prosthesis, it is best to seek urologic consultation. Other genital surgery procedures such as vasectomy, testicular biopsy, reconstructive microsurgery for fertility treatment, and orchietomy for tumor or benign disease can be complicated by bleeding or infection. If marked swelling occurs following genital surgery, the urologist should be immediately made aware. Orchietomy for tumor is performed through an inguinal incision and involves removing the testis, its investing tunics, and the spermatic cord to the level of the internal inguinal ring. If bleeding occurs from the stump of the spermatic cord, hematoma can develop in the retroperitoneum and require high exploration for control.

UROLOGIC TRAUMA

Trauma centers vary markedly with regard to the role played by the urologist in trauma management. Some highly respected centers utilize the urologist’s expertise routinely for assistance with the management of genitourinary injuries, while others
include the urologist only selectively. At our trauma center, the urology service plays a central role in the assessment and management of urologic injuries, participating in the selection and interpretation of imaging studies, the decision of when to operate, and the operative intervention itself (13). As such, we have achieved a high level of cooperation between our service and the trauma surgery and critical care medicine services.

Herein, we will address the basic approach to the diagnosis and management of urologic trauma, with a recommendation that the urologist be included whenever feasible in management decisions (14). We will address management of iatrogenic urinary tract trauma, followed by trauma from external violence for renal, ureteral, bladder, urethral, and genital injuries with regard to assessment and management, and discuss the relevance of damage control strategies in urologic trauma. The urologist's experience in elective urologic surgery; endoscopic, radiologic, and open surgical intervention; reconstructive approaches; and management of complications may be very helpful to the trauma and critical care teams when faced with the multiply injured patient or one with solitary urologic organ trauma. When no urologist is available, however, or when critical care decisions need to be made in the absence of urologic input, the intensivist or the acute care/trauma or general surgeon must have a working knowledge of the approach to the most common and important types of urologic trauma.

Evidenced-based Urologic Trauma guidelines have recently been published through both the U.S. and international urologic professional organizations; those with an interest in this specialized area of trauma care may find these reports of particular interest (11,15).

Iatrogenic Injury Management

The concern for, or recognition of, the occurrence of an iatrogenic urologic injury provokes significant anxiety in the surgical team. Having a basic concept of the common forms of injury, the procedures introducing significant injury risk, and the standard approach to management is essential in maintaining a focus on prompt resolution of the problem (16-19).

For uncomplicated bladder injuries, simple suture closure is feasible as long as the injury involves the upper bladder segment, the trigone is uninjured, and there is no significant tissue loss. A running, two-layer closure using heavy absorbable suture is standard. A generously sized IUBC should be used—20 French or larger—to allow drainage of bloody efflux and allow efficient irrigation when needed. If the bladder wall surrounding the injury is markedly abnormal (fibrotic, friable, irradiated), a two-layer closure may not be feasible. In these cases, we prefer a one-layer, interrupted closure with heavy suture, with a plan to leave the bladder catheterized for a longer period of time.

If there is involvement of the trigone, ureteral orifices, or intramural ureters, the situation is more complex, and ureteral stent insertion or ureteral reimplantation may be needed. This is best accomplished with urologic support, and may involve placing an externalized single-J or internalized double-J ureteral stent, then suturing the bladder injury. If a stricture ultimately forms, endoscopic management or delayed elective ureteral reimplantation is always an option. Feeding tubes may also be temporarily passed up the ureters during the bladder repair to identify and protect the ureters, and support performing a safe cystorrhaphy (bladder repair). Prophylactic insertion of externalized ureteral catheters prior to complex pelvic or retroperitoneal surgery may be helpful in avoiding surgical injury to the ureter, though their efficacy in reducing the risk of ureteral injury is not universally accepted (20).

For iatrogenic ureteral injuries, the approach for repair depends on the level of injury, whether there is loss of ureteral length, the condition of the ureter and surrounding tissue, and the comfort of the surgeon. Traditional urologic teaching states that if the ureter is transected caudal to the crossing of the internal iliac artery, a reimplantation rather than a primary anastomosis should be performed. This policy reflects the concern for the viability of the distal ureteral stump in the setting of abnormal pelvic anatomy and surgical insult. The reimplantation can be performed with or without a “psa hitch”—sutting the upper bladder segment to the ipsilateral psoas muscle fascia—depending on ureteral length and bladder status. For injuries in the mid or upper ureter, primary, spatulated anastomosis performed over an indwelling stent is the preferred solution. As long as one is dissecting outside the ureteral adventitial sheath, substantial length can be gained by mobilizing the ureter toward the kidney and deep into the pelvis with devascularization unlikely. If primary ureteral repair is not possible, the options include ligation followed by nephrostomy insertion and planned delayed reconstruction, transureteroureterostomy, renal autotransplantation, or ileal ureteral replacement, neither of which is usually appropriate in the acute care surgery setting.

When dissecting in the groin, especially in the setting of a redo hernia, the spermatic cord is at risk for injury. If there is injury to cord vasculature, precise suture ligation of bleeding points should occur, as a hematoma around the cord is very problematic. If there is concern for devascularization of the testis, use of a fine-tipped Doppler probe to detect an arterial pulse distal to the area of dissection or over the testis itself is helpful. Even if one is quite concerned that most of the cord vasculature has been lost, we would generally recommend leaving the testis in place and observing it, as the testis has redundant blood supplies—internal spermatic, external spermatic, and vasal arteries, which come from aortic, external iliac, and internal iliac sources, respectively—and may survive on collateral blood supply. The status of the testis can be addressed postoperatively.

Penetrating and Blunt Trauma to the Genitourinary System

General Evaluation

Diagnosis of urinary tract injury is typically based on history and mechanism of injury, physical examination, laboratory assessment, and the findings on imaging studies (21). Any patient with a history of gross hematuria following trauma should be imaged, unless of course he or she is unstable and/or must be taken directly to surgery (22). In addition, current literature supports obtaining contrast imaging studies for patients with microscopic hematuria and hypotension at any time following trauma, as well as those patients with significant deceleration mechanisms of injury and other injury factors that portend a high risk of urinary tract injury, such as lower posterior rib fracture, transverse spinal process fracture, or pelvic or femur fracture. The contrast-enhanced CT scan of the abdomen and pelvis has become the standard study of
choice for assessment of hematuria, for staging of injuries in the trauma setting, and for the evaluation of renal or ureteral injuries. The “shock room intravenous pyelogram (IVP)” has fallen out of favor, provides much less information than the CT scan, and is uncommonly utilized. Bladder injuries may be suspected based on the presence of gross hematuria following pelvic trauma, with confirmation by either standard radiographic or CT cystography. Adequate bladder filling must be accomplished to demonstrate extravasation and minimize false-negative studies. When urethral injury is suspected following pelvic fracture or perineal or genital trauma, especially when blood is exiting from the urethra or present at the urethral meatus, retrograde urethrography should be performed prior to any attempt at urethral catheterization, to avoid exacerbating a partial urethral rupture. For genital trauma, scrotal ultrasonography may be of great value in diagnosing testicular rupture from blunt forces; in penetrating genital trauma, surgical exploration is usually necessary and one can often forego genital imaging studies.

**Urethral Injuries**

These are suspected in cases of pelvic fracture, particularly with severe pubic diastasis and vertical shear injuries. A urethrogram that demonstrates contrast extravasation is diagnostic (23). Some urologists may be comfortable with a careful attempt at catheter insertion under cystoscopic guidance, or a fluoroscopically and endoscopically guided catheter realignment procedure, though whether this approach provides outcome advantages over traditional SP diversion remains controversial (24,25). The standard approach remains immediate postinjury SP tube insertion. Certainly any nonurologist should handle such injuries with placement of an SP catheter, obtaining urologic consultation when available. SP cystostomy insertion may be accomplished using trochar-based percutaneous systems if the bladder is adequately distended and the required kit is available. If not, or if most expeditious—as for a patient undergoing an emergent laparotomy—an open surgical approach in the OR is preferable. Blunt trauma to the perineum with crush injury and complete bulbar urethral rupture is also best handled with SP diversion. Penetrating injuries to the urethra can be managed in a delayed fashion with SP diversion or, if the injury is readily apparent and accessible, direct suture repair with fine absorbable suture may be attempted in the stable patient. All such injuries can be managed in a delayed fashion as long as proximal urinary diversion is achieved acutely. In the absence of advanced specialty expertise, temporary SP tube diversion and referral to a reconstructive urology center is a wise strategy.

**Bladder Injuries**

These are most often diagnosed on cystography (26) or by gross intraoperative observation. Many blunt injuries to the bladder can be managed with catheter drainage alone, if the injury is uncomplicated and extravertoreal; this type of bladder trauma is often related to pelvic fracture. An adequate-bore IUBC—20 French or larger—is preferable to evacuate grossly bloody efflux. If there is failure of catheter management, such as continued profuse hematuria with repeated occlusion of the catheter or continued urinary extravasation, surgical repair may be necessary. If it is necessary to surgically repair such an injury, a high midline cystotomy should be made to avoid entering into a fresh retroperitoneal hematoma, the result of which could result in problematic bleeding. The laceration may be sutured in a single layer transvesically by placing retractors into the bladder and exposing the injury. Other variants of extravertoreal bladder injury that benefit from surgical repair, as opposed to catheter drainage alone, include those which involve communication with a vaginal or rectal injury, or are in communication with an open pelvic fracture. An SP tube, in addition to the urethral IUBC, may be left indwelling in cases in which the repair is tenuous or prolonged tube drainage is anticipated, such as in closed head or spinal cord injuries. In uncomplicated cases, performing a contrast cystogram via the IUBC at approximately 10 to 14 days post injury, and prior to catheter removal, ensures complete healing before stressing the bladder.

For **extravertoreal** bladder injuries direct suture repair is required. Such injuries result in entry of urine directly into the peritoneal cavity, which must be controlled to avoid urinary ascites, sepsis, azotemia, and other complications. These injuries typically result from sudden compression of the full bladder—such as from a blow to the lower abdomen, or seatbelt compression in a motor vehicle crash—causing a large bladder dome laceration. Transabdominal suture repair is straightforward; under appropriate circumstances, such repair may be performed laparoscopically with success. We generally place a urethral IUBC and do not use SP tubes in such cases.

**Ureteral Injury**

These are usually noted upon abdominal exploration in the penetrating trauma setting, or may be noted by observing urinary extravasation on preoperative CT scanning (27). It is necessary to obtain a delayed excretory phase on the CT such that the excreted contrast column has transited the entire ureter, or the risk of missing a ureteral injury is significant. Injuries from penetrating trauma are managed similarly to the approach described above for iatrogenic injuries, or by applying damage control techniques when necessary (see below). For gunshot wounds to the mid and upper ureter, limited debridement to the viable ureter, careful extra-adventitial mobilization, and spatulated suture anastomosis is appropriate. For distal ureteral injuries, reimplantation into the bladder (ureteroneocystostomy) is a more dependable approach, as the problem of the distal stump having impaired vascularity is avoided. Ureteral injuries from blunt trauma are rare; exceptions would include the pediatric population, where ureteropelvic avulsion injuries or renal pelvic lacerations may occur following blunt injuries. When major injury occurs to the urinary tract following seemingly trivial trauma, one should be suspicious of the presence of previously existent underlying pathology of the urinary tract such as neoplasm or congenital ureteropelvic junction obstruction.

**Renal Injuries**

These are typically staged by contrast-enhanced CT using the American Association for the Surgery of Trauma (AAST) Organ Injury Scaling system (28,29). Renal injuries are managed according to a multifactorial decision process that considers injury grade, whether due to blunt or penetrating forces, patient clinical status and hemodynamic stability, and the presence of other nonurologic injuries (30,31). In general, for **blunt renal injury**, grade I, II, and III injuries are routinely managed nonoperatively. **Grade IV** injuries, which involve deeper, significant parenchymal injury and laceration to the collecting system, or branch renal vessel injuries, require a selective approach, largely influenced by hemodynamic...
parameters and degree of progressive blood loss, and often warrant ICU monitoring to address whether continued bleeding or urinoma formation occurs, which may warrant delayed intervention (32). The majority of such injuries in most series do not require early exploration, and the observation of extravasation from the collecting system is not, in itself, an absolute indication for surgical exploration. If there is extensive medial extravasation on CT, retrograde pyelography may be indicated to exclude a major injury to the renal pelvis or proximal ureter. Grade V injuries from blunt trauma routinely require surgical exploration and often nephrectomy; most reported results of attempts to manage true grade V injuries nonoperatively have not resulted in favorable outcomes. Renal pedicle injuries, considered in both the grade IV and V groups, require careful consideration to select appropriate management. When the kidney suffers a pedicle stretch injury from deceleration trauma, resulting in arterial intimal disruption, the artery can thrombose, resulting in renal devascularization (33); this can be diagnosed on CT scan with the finding of renal nonperfusion. If the vessels are thrombosed but not avulsed or lacerated, the decision of whether to operate to revascularize the kidney depends on how much time has elapsed—which predicts renal salvage—as well as the patient’s other injuries and ability to tolerate a laparotomy. After 30 minutes of warm ischemia, irreversible renal damage begins; by 3 hours, the kidney is probably not retrievable. If there is a pedicle avulsion injury, surgery is mandatory to prevent early or delayed catastrophic bleeding.

For penetrating renal trauma, the standard approach has traditionally been surgical exploration and repair, or nephrectomy. This view has evolved over the past two decades, however, with reports demonstrating favorable outcomes from nonoperative management of carefully selected penetrating injuries. It has been reported that up to 50% of renal stab wounds and over 20% of renal gunshot wounds may be successfully managed nonoperatively. When comparing the approach to blunt versus penetrating trauma, one must consider the high likelihood of there being associated injuries in penetrating trauma. Still, a fully staged penetrating kidney injury—based on CT—may be appropriately managed nonoperatively if certain conditions are met. These include, in my view, a lateral or polar parenchymal injury, which spares the renal sinus or deep central region of the kidney; a hemodynamically stable patient; a low suspicion of injury to the extrarenal collecting system or ureter. The larger the renal hematoma, the less comfortable I am with nonoperative management of a penetrating renal injury. Proactive angiography may be considered when weighing the safety of a nonoperative approach to the penetrating renal injury in selected cases; admission to the ICU is essential to monitor for renewed bleeding. It should be stated for the intensivist that the default mode for penetrating trauma to genitourinary organs is operative exploration and repair; departure from this approach is appropriate when complete staging information is available that predicts a favorable outcome for a specific injury with a nonoperative approach, the patient is hemodynamically stable, and careful monitoring for failure of nonoperative management can be carried out. Criteria and a plan for changing to an operative strategy should exist.

Genital Injuries

These require specialized care and should be handled by practitioners experienced in genital surgery. As a general principle, a very conservative approach to genital debridement should be maintained, with tissues of questionable viability reassessed in a delayed fashion. Nearly all penetrating genital injuries should be acutely surgically explored, assuming the patient is sufficiently stable to undergo a reconstructive effort. Penetrating penile injuries are repaired surgically by closing lacerations to the tunica albuginea of the corpus cavernosum, urethral repair, and skin and soft tissue reconstruction. Penetrating testicular injuries can usually be repaired by closing the tunica albuginea of the testis after debriding nonviable testicular parenchyma. Blunt fracture of the penis, which results from forcible flexing of the penile shaft during erection—often due to trauma during intercourse—should be explored and repaired acutely upon presentation, to achieve the most favorable cosmetic and functional outcome. For blunt scrotal injury, it is often useful to assess the patient with scrotal ultrasonography to determine if testicular rupture is present; it may be difficult to determine this on physical examination if there is scrotal wall swelling, which makes identification of internal structures difficult. Ultrasound is quite accurate for detecting testicular rupture: loss of capsular continuity or marked heterogeneity of testicular parenchyma is predictive of rupture. Testicular salvage is enhanced by early exploration and repair.

Damage Control Strategies for the Management of Urologic Injury in the Unstable Patient

Damage control approaches to the management of the unstable trauma patient have become well accepted in the trauma center setting. This concept refers to abbreviating the initial operative effort in order to minimize the effects of prolonged surgery, which results in progressive metabolic deterioration. Critical injuries—surgical bleeding, fecal contamination sources—are addressed, while noncritical injuries are handled in a delayed fashion, on a subsequent visit to the OR after ICU stabilization. This approach avoids development of the “lethal triad” of progressive acidosis, hyperthermia, and coagulopathy, which occurs in critically injured patients when initial surgical efforts are prolonged. Many urologic injuries are quite amenable to initial management by applying damage control strategies (34). With the exception of severe renal or bladder bleeding cases, urinary tract injuries rarely directly result in early mortality. When, in the surgeon’s judgment, the patient would not tolerate the magnitude of reconstructive effort needed to deal definitively with a urologic injury at initial laparotomy—due to pattern of injury, hypothermia, acidosis, coagulopathy, or other parameters that mandate a damage control approach—certain temporary solutions may be very desirable (35). We have gained substantial experience with such approaches in our center, and have achieved an effective working relationship with the trauma surgeons in patient selection and technical approach for such cases.

Renal injuries that are incompletely staged, or unstaged, may be approached with delayed assessment and exploration, as long as a determination is made that early exsanguinating bleeding from the injury is unlikely. In the absence of significant bleeding from the renal fossa into the peritoneal cavity, a large midline hematoma, or an expanding or pulsatile renal hematoma, one can elect to leave the perinephric hematoma undisturbed and either obtain postoperative imaging during the resuscitation phase following initial laparotomy, or
explore at the time of a second-look procedure. If the kidney is already surgically exposed, hemostasis for major bleeding from parenchyma or branch renal vessels can be rapidly obtained. If a major reconstructive effort is still needed in the unstable patient, packing the kidney and returning for reconstructive interventions later is also an option.

Ureteral injuries may be initially managed with externalized stenting, ligation, or simple local drainage. Of these options, we favor externalized stenting, as it allows control of the urinary output, minimizes ongoing urinary extravasation, and can be maintained for several days until the patient is stable enough to return to surgery for definitive reconstruction. A 7-French or 8.5-French single-J urinary diversion stent can be placed into the ureter through the injury site and advanced proximally into the kidney, then externalized through the abdominal wall. The stent should be tied to the very end of the injured ureter at the injury site, so as not to lose ureteral length by ligating it more proximally and making later reconstruction more challenging. The distal ureteral limb is best left undisturbed; ligating it requires subsequent debridement and causes further tissue loss.

A similar approach can be utilized for extensive bladder injuries: the ureteral orifices can be catheterized, the catheters externalized, and the pelvis packed, leaving bladder reconstruction to be performed at a more suitable time, following appropriate resuscitation. Urethral and genitourinary injuries are also amenable to damage control approaches, generally involving tube urinary diversion, placement of moistened dressings, and tissue preservation until definitive reconstruction following appropriate resuscitation.

**UROLOGIC TUBES AND DRAINS FOR THE INTENSIVIST**

Tube drainage and diversion of the urinary tract and adjacent areas constitute important and commonly employed strategies in urologic care and urologic surgery. The safe insertion, maintenance, and management of such tubes are essential to avoid preventable morbidity and support appropriate medical and surgical management. The frequently utilized tubes that may be encountered by the critical care provider include nephrostomy, SP cystostomy, IUBC (urethral Foley catheter), and internal ureteral stents. In addition, externalized drains are often placed near the site of urologic surgery or injuries and employed for various purposes including drainage of blood, infected fluid, lymph, or extravasated urine. The general principles behind urologic tube drainage along with specific management considerations for the different types of tube mentioned above will be addressed in this section (36,37).

Tubes placed within the urinary tract may be intended as temporary or permanent solutions to various urologic problems, including bladder muscle failure and obstructive upper or lower tract lesions. Patients with detrusor muscle failure require regular bladder emptying, which may be managed by intermittent catheterization—typically utilizing a clean/non-sterile technique—or by an indwelling catheter; in the case of indwelling catheters, the options include an IUBC or an SP cystostomy tube. In the male, due to the potential morbidity of a long-term IUBC—including urethral erosion, periurethral abscess, epididymitis, and traumatic hypospadias—the SP tube is often favored. Nearly all patients with indwelling bladder catheters of either variety will become bacteriuric, but patients with SP tubes are less likely to develop the list of urethral catheter-related complications noted above. In women, long-term urethral catheters are better tolerated, though the urethra may gradually become dilated and capacious, resulting in troublesome leakage around the tube.

**Urethral Catheters**

Urethral catheter placement techniques are well known. If a standard IUBC is needed but resistance is met during placement, it is important not to force the catheter into the urethra, which risks urethral mucosal perforation, creation of a false passage, and bleeding, greatly complicating further catheterization attempts; this principle is relevant both to the trauma and nontrauma setting. The catheter balloon should not be inflated until urine return is assured; if no urinary drainage occurs upon catheter insertion, aspiration of the catheter using a piston syringe should occur before balloon inflation. In general, most catheter balloons should be inflated with a full 10 mL of saline or water to avoid inadvertent distal balloon migration into the urethra. Some balloons are rated to 30-mL inflation volume or greater; this information is clearly printed on the catheter inflation hub. If a standard catheter will not advance into the bladder, options include trying a smaller catheter, using a Coudé catheter, or requesting urologic consultation. If obstruction is met deep in the urethra in the male, the Coudé catheter is particularly helpful, as the curved tip will often navigate over an enlarged prostate and bladder neck and solve the problem. If resistance is met more distally in the penis or distal bulbar urethra, a stricture may be present for which a smaller catheter may be of benefit. Beyond these measures, the safest approach is to seek urologic expertise to assist with bladder access.

In the female, urethral catheter insertion is seldom difficult; true urethral strictures are uncommon—seen occasionally following radiation therapy or local surgery—as the urethra is generally straight and short. At times, due to atrophic changes, the female urethral meatus may be difficult to identify visually. In such cases, the meatus is often retracted onto the distal anterior vaginal wall. We can typically palpate it with a gloved fingertip and guide a catheter into the appropriate location. Problems in placing a female urethral catheter not solved by the above technique or by using a smaller tube may indicate significantly abnormal anatomy and should prompt urologic consultation.

In the hospital setting, patients often arrive in the ICU with an indwelling catheter in place. It is important to verify that, on arrival, the catheter is properly positioned and is draining properly. It is remarkable how often we are consulted for a mysteriously malfunctioning catheter only to find that most of the catheter shaft length is outside the meatus, and the balloon is easily palpable in the perineum or penis, plainly indicative of malposition. If a catheter appears properly positioned but fails to drain, it should be irrigated with 60 to 120 mL of normal saline or water; it should be possible to infuse and withdraw the instilled irrigant. If the catheter is not draining spontaneously and one can infuse but not withdraw fluid, the catheter may be malpositioned and will likely require repositioning or replacement. When changing a chronic indwelling catheter for routine purposes (generally monthly is advised), choose a convenient time when help is readily available in case difficulty is
encountered, not in the middle of the night shift. If a patient forcibly removes a catheter with the balloon inflated, dramatic urethral bleeding often occurs. Catheter replacement is typically necessary, and may be difficult due to deep laceration of the urethral mucosa. We would recommend trying to pass a Coudé catheter with the tip pointed cephalad; if not successful, obtain urologic assistance. The cost of iatrogenic urinary catheter-related trauma is considerable; this common procedure should be carried out with due respect and caution, with a liberal approach to urologic consultation when challenges arise (38).

Suprapubic Cystostomy Tubes

SP cystostomy tubes are straightforward devices that may be used as a temporary bladder drain or as a permanent strategy as noted above. SP tubes can be placed in the awake patient under local anesthesia using trochar-based kits, or can be placed through an open surgical approach under anesthesia in the OR. If placed percutaneously, it is essential that the bladder be well distended prior to insertion. If this is not the case, the trochar—over which the catheter is advanced—can penetrate fully through the bladder lumen and pierce the posterior bladder wall, causing bladder injury and potentially injuring the vagina or rectum, or can injure intraperitoneal structures; signs of such adjacent organ injury should prompt immediate surgical and urologic consultation. Once in place, an SP tube should generally be left indwelling for at least a week so that an established track forms between the skin and the bladder lumen. If an SP tube is intended to remain indwelling for an extended period, we prefer to perform the first tube change after at least a month, so that a mature track will be present. If prematurely removed, extravasation of urine into the retroperitoneal and perivesical space may occur, which can result in urine absorption, azotemia, or urosepsis. A long-term indwelling SP tube through an established track is usually easy to change by simple removal and replacement with the same caliber and type of tube. Occasionally the track may be oblique or tortuous and direct visualization with a flexible cystoscope by a urologist and placement of the new tube over a guidewire may be necessary. If an SP tube is inadvertently removed or displaced, the track may close within a matter of hours, certainly over the course of a day or so, even when the tube has been in place long term. It is important that tube replacement be accomplished promptly to avoid track closure and the need to reestablish access in a more invasive manner.

It is important to realize, as noted above, that nearly all indwelling urinary tract tubes that communicate with the external environment will result in bacteriuria, often within about 10 days of tube placement (39). In most cases this is a harmless process and does not result in clinical infection. If, however, urinary tract manipulation or an invasive urinary tract procedure is planned, instrumentation in the face of such bacteriuria may precipitate urosepsis, as the tissues are vulnerable to intravasation of bacteria when a chronic catheter has been present. It is beneficial to obtain urine culture data and institute therapy with culture-specific agents prior to significant instrumentation of the chronically catheterized urinary tract, to minimize the risk of iatrogenically induced clinical infection or urosepsis.

The same principle applies when considering removal of an indwelling bladder tube, especially when there is the potential for the patient failing a voiding trial and developing urinary retention following catheter removal, as in BPH patients with episodic retention who may or may not pass a voiding trial. If a patient with catheter-related bacteriuria develops urinary retention upon catheter removal, the risk of clinical infection or urosepsis is significant. These patients, as well, should have coverage with culture-specific antibiotics whenever possible, or at least have the provision of empiric broad-spectrum urinary antibiotics—fluoroquinolone or extended-spectrum penicillin derivative—prior to a voiding trial. Such patients are likely to have resistant organisms, as they have often been in the hospital environment.

Nephrostomy Tubes

Nephrostomy tubes are placed directly through the renal parenchyma into the collecting system to provide proximal ipsilateral urinary tract drainage and diversion. They may be placed percutaneously under fluoroscopic, CT, or ultrasound guidance in an IR suite, or in the OR as part of a urologic surgical procedure through radiologic, endoscopic, or open techniques. Several types of tube are available and intensivists should know what type of tube they are dealing with. Most commonly used are the loop nephrostomy tubes, which have some type of retention system, usually consisting of a pull-string that is deployed upon tube placement to allow it to be retained effectively within the collecting system. Percutaneously placed tubes are usually in the range of 8 to 12 French in size and are attached to drainage bags with connector tubing. Tubes placed as part of percutaneous stone or other upper tract surgical procedures may be larger; often IUCs ranging from 16 to 24 French in size are employed. In such cases the tube is usually sutured to the skin for retention, as inflating the balloon is problematic in the renal collecting system and may impair drainage or stress or tear the delicate collecting system wall. Intensivists should be entirely clear as to what is expected with regard to such tubes under their care; a conversation with the urologist or whomever is responsible for the tube insertion and familiar with its specific purpose is desirable: Is it expected to drain continuously? What action should be taken if it fails to drain? How should bloody efflux be interpreted or acted upon? The purposes of these tubes may vary from providing a large-bore drain after a bloody percutaneous lithotripsy to a small tube placed only to drain urine for an obstructed ureter. It may be safe to irrigate nephrostomy tubes if they fail to drain, but again, this should be arranged by specific order, and assumptions regarding the purpose and management approach to such tubes introduce unnecessary risk. When irrigating a nephrostomy after determining that doing so is safe and appropriate, a small volume of saline—5 to 10 mL—should be utilized. If, in the postoperative urologic surgery setting, a nephrostomy tube begins to drain blood at an alarming rate, the best course of action may be to clamp the tube, address hemodynamics urgently, and rapidly call the urologist for instructions. As for other tubes mentioned above, the collecting system will become colonized with bacteria after being indwelling for a week or so, and clamping trials, manipulation, or tube removal is best done following provision of culture-specific or at least empiric antibiotics (37,40).

Internal Ureteral Stents

Internal ureteral stents are commonly used in urology, often for the purpose of relieving ureteral obstruction, but also
following urologic surgery or trauma to allow low-pressure drainage or provide urinary diversion while the trauma of surgery or local edema or inflammatory changes are allowed to resolve. The most common variety of stent is the internal double-J stent; these stents have a loop in the bladder and a loop in the kidney. They are placed either retrograde via cystoscopy or antegrade during open or percutaneous surgery, over a guidewire. The proximal and distal coils form upon removal of the guidewire. Typical sizes in adults are 6- to 7-French caliber and 22 to 28 cm length, depending on the patient's height and ureteral length and tortuosity. Some stents include a pull-string on the distal coil, which, at the urologist's discretion, may be either cut short or allowed to exit the external urethral meatus to aid in subsequent removal without requiring repeat cystoscopy. Patient care personnel should be instructed as to the presence of a pull-string and should be aware of the importance of not pulling on it or allowing the patient to do so. Stents are of great value in urologic surgery but they do have their pitfalls, mainly related to their small caliber and proneness to obstruction, the potential for them to migrate and become malpositioned, their tendency to cause unpleasant flank or bladder symptoms, and the risk that they may be forgotten and lost to follow-up. In the ICU, the major issues relate to obstruction, migration, or infection. Significant flank pain, chills or fever, or a change in stent position on serial abdominal radiographs should prompt urologic consultation to address these stent-related complications. Stent occlusion with resultant ureteral obstruction, in the setting of proximal infection, is a surgical emergency that may result in sepsis, and require immediate urologic intervention in the form of endoscopic stent replacement or urgent nephrostomy insertion. Many stents are certified for a 3- to 6-month maximum indwelling time, after which they need to be changed to avoid calcification and obstruction. Some stents are specifically designed for long indwelling times—used for persistent obstructive states such as benign or malignant retroperitoneal fibrosis or postradiation strictures—of up to 12 months. There are stents that combine the function of an externalized nephrostomy and an internal stent; these are usually termed nephrostents or “universal stents.” They can be capped at the flank entry point and made to drain internally, or may be un capped to drain as an externalized nephrostomy tube. Nephrostomy change or removal and stent change or removal should only be performed by a urologist or interventional radiologist or upon his or her specific direction.

For a patient presenting with symptomatic upper tract obstruction, such as for an obstructing ureteral calculus, the option often exists to observe, or provide relief with stent insertion or nephrostomy placement (41), depending on the details of the clinical situation. The decision of how to manage such patients acutely depends on the ability to get the patient to either the cystoscopy suite or the IR suite more expeditiously, the expertise available, and the clinical picture. For acutely ill patients with an obstructed, infected upper tract, many urologists prefer to have IR place a nephrostomy tube percutaneously, control the infection, and then reserve any retrograde instrumentation or definitive stone management for an elective setting. If the patient is coagulopathic or anticoagulated, a retrograde cystoscopic approach may be safer, as the radiologist will be quite reticent to enter the kidney percutaneously when the coagulation functions are abnormal for fear of creating a major hemorrhagic complication.

### Closed Suction Drains or Penrose Drains

These drains may be left in place following urologic surgery to allow external drainage of blood, urine, lymph, or infectious fluid. From the intensivist viewpoint, the urologist should be asked specifically what should be expected regarding appropriate function of the drain and exactly what parameters should be a cause for concern: Is significant blood output expected? Is continuous drainage important? Under what circumstances should the surgeon be informed urgently? Urine leaks following certain types of urologic surgery, such as some partial nephrectomies for trauma, may be expected, and if adequately drained externally, seldom constitute an emergency. Elevated blood output may be an indication of internal bleeding and should prompt a call to the surgeon if there is any doubt as to whether the situation is acceptable.

As a general statement to the ICU team, urologic drainage tubes have widely varying purposes and specifications and should be managed in concert with the surgeon who placed them or is responsible for them to avoid confusion and preventable complications.

### Urinary Diversion Management from the ICU Perspective

Beyond the considerations regarding tube diversion or drainage, some patients under the critical care team’s care may have undergone, either acutely or remotely, a surgical urinary diversion procedure, most commonly utilizing a bowel segment. The variety of such diversions is considerable, and the ICU team deserves a full explanation of the patient's anatomy and how to deal with any problems that may arise. Urinary outflow obstruction, intra-abdominal urinary extravasation, infectious complications, and problems with the intestinal anastomosis may occur with any type of urinary diversion. One can divide urinary diversion procedures into conduits and reservoirs, and reservoirs may be subdivided into cutaneous and orthotopic. Conduits are simple surgical reconstructions that allow urine to exit to the outside and do not involve an internal urinary reservoir (42). An ileal conduit is one of the most commonly encountered urinary diversions, often performed following cystectomy for lower urinary tract cancer, but also at times for neurogenic or inflammatory disease or devastating pelvic trauma. In this procedure, a segment of distal ileum is isolated from the fecal stream, followed by a small bowel anastomosis to reestablish intestinal continuity. The proximal end of the isolated segment is closed and the distal end is brought to the skin of the abdominal wall as a stoma. The ureters are sutured into the conduit intra-abdominally to route the urinary stream externally. Most ileal conduits seen acutely by the ICU team in the immediate post-surgical period have indwelling tube drainage present—often externalized stents that enter the stoma, travel up each ureter to allow the ureterointestinal anastomosis to heal, and avoid obstruction or urinary extravasation in the early postoperative period. A second tube, often a simple straight catheter segment, may also be placed from outside the stoma to inside the conduit beneath the abdominal wall fascia to allow conduit drainage.

Other conduits employed in urologic surgery may utilize other bowel segments, including jejunum and descending or
Reservoirs (neobladders) involve the use of larger segments of intestine to fashion a neobladder reservoir internally, along with some form of urinary efflux mechanism, often designed to create a continent diversion that the patient can catheterize—and not wear a urinary collection appliance—or that is sutured to the native urethra, in either the male or female, to allow restoration of voiding (an “orthotopic neobladder”).

While conduits may be complicated by obstruction or urinary leakage as noted above, and the same issues can arise in neobladder reservoirs, the reservoir urinary diversions can develop certain other potentially serious problems including “pouchitis,” pouch rupture, and formation of pouch calculi. These issues require specialty input and prompt urologic consultation. The issue of pouch rupture, however, deserves specific mention as this must be promptly recognized. Any patient with signs of abdominal infection, peritonitis or sepsis who has a neobladder should raise the suspicion of pouch rupture. This entity can also be seen in patients who have had an augmentation cystoplasty, in which a segment of bowel is added to the native bladder to increase capacity or deal with severe and intransigent overactive bladder symptoms. Such patients should have urgent urologic assessment, which may involve contrast imaging studies—CT or “pouchography”—to rule out urinary leakage intra-abdominally. Broad-spectrum antibiotics should be instituted early in such cases, as the urine is often colonized and intra-abdominal infection may develop. Many such cases of minimal or contained rupture can be managed with tube drainage of the neobladder alone although, in some cases, surgical exploration and repair, and/or evacuation of infectious fluid from the abdominal cavity are necessary.

Depending on the type of urinary diversion and the specific segment of the gastrointestinal tract used for the reconstruction, these patients may be at risk for dehydration, and specific electrolyte and metabolic disturbances may be seen (43,44). The significance of these problems is related to the portion of the gastrointestinal tract utilized for the diversion and the length of time the urine is exposed to the bowel surface. Jejunal conduits may result in hyponatremic, hypochloremic metabolic acidosis; this process may be clinically manifested by “pouchitis,” pouch rupture, and formation of pouch calculi. These issues require specialty input and prompt urologic consultation. The issue of pouch rupture, however, deserves specific mention as this must be promptly recognized. Any patient with signs of abdominal infection, peritonitis or sepsis who has a neobladder should raise the suspicion of pouch rupture. This entity can also be seen in patients who have had an augmentation cystoplasty, in which a segment of bowel is added to the native bladder to increase capacity or deal with severe and intransigent overactive bladder symptoms. Such patients should have urgent urologic assessment, which may involve contrast imaging studies—CT or “pouchography”—to rule out urinary leakage intra-abdominally. Broad-spectrum antibiotics should be instituted early in such cases, as the urine is often colonized and intra-abdominal infection may develop. Many such cases of minimal or contained rupture can be managed with tube drainage of the neobladder alone although, in some cases, surgical exploration and repair, and/or evacuation of infectious fluid from the abdominal cavity are necessary.

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Other metabolic abnormalities seen with urinary diversion procedures may include altered bile salt metabolism following ileal resection, which can affect fat digestion and uptake of vitamins A and D; malabsorption and steatorrhea and a propensity to develop cholelithiasis may also be associated with ileal resection; and gastric or ileal resection may cause vitamin B12 deficiency, which can lead to megaloblastic anemia and peripheral nerve dysfunction, for which B12 nutritional supplementation may be indicated.

Other complications include stomal stenosis, recurrent upper tract urinary infection and deteriorating renal function, and calculus formation in the upper tract or within the diversion conduit or reservoir. Stomal stenosis may cause obstructive uropathy requiring catheterization and stomal revision. Catheter insertion into a conduit or reservoir construct may be challenging; if difficulty is encountered, a small-bore Coudé catheter may be useful, as may use of fluoroscopy to guide catheter positioning. Stomal bleeding is usually superficial and manageable with local compression or minimal cautery when necessary. Parastomal hernias may occasionally become incarcerated requiring urgent surgical intervention. Azotemia and upper tract dilation may be problematic, especially when more than 10 years have elapsed since the diversion. Upper tract deterioration is seen in at least 50% of patients who have undergone urinary diversion during childhood or young adult years, and the risk of developing chronic renal insufficiency is increased in such patients. Calculi occur in roughly 8% to 10% of urinary diversion or bladder substitution patients, where urease-producing organisms—Proteus, Pseudomonas, Klebsiella, etc.—are the bacteria commonly seen.

UROSEPSIS AND COMPLEX UROGENITAL INFECTION IN THE ICU

Urosepsis has been addressed in several sections within this chapter, related to trauma, urologic tubes and drains, and below in renal failure management. It is also addressed elsewhere in this text (Chapters 46, 84, 87–92) with regard to general management principles for sepsis and septic shock (2,3,45–50). In addition, there are several specific urologic infectious disease phenomena that warrant specific mention.

Specific Infectious Processes of the Upper and Lower Urinary Tract

The combination of obstruction and infection of the upper and lower urinary tract requires urgent drainage, antibiotic therapy, and supportive care. Initial empiric antibiotic therapy for possible urosepsis must address the likely offending organisms and must consider the “worst-case scenario” from the bacteriologic standpoint. While awaiting culture data, Gram stain findings can also be very helpful in selecting initial therapy. Broad-spectrum antibiotics that cover aerobic gram-negative rods and the typical gram-positive cocci that appear as uropathogens are critical. If the patient has been recently instrumented, has been recently hospitalized, or has other risk factors for having sepsis due to atypical or resistant pathogens, coverage should be expanded accordingly. The newer-generation cephalosporins, imipenem, meropenem and related drugs, aminoglycosides, and vancomycin are commonly used in such circumstances. It may be necessary in certain situations to consider the presence of anaerobic infections of the genitourinary system. Sepsis following transrectal prostate biopsy procedures—typically ultrasound-guided and office-based—may introduce the risk of anaerobic infection. I am aware of deaths where a patient presented with urosepsis and retroperitoneal
cellulitis following a needle biopsy of the prostate, in which anaerobic coverage was not provided and, ultimately, death from *Bacteroides fragilis* infection occurred. Anaerobic infection of the urinary tract has also been described outside the setting of iatrogenic rectal violation, both with enteric fistula and without identifiable anaerobic source, so this uncommon scenario is worth bearing in mind (51). Staphylococcal infections of the urinary system do also occur, particularly in the elderly or immunocompromised population, and in patients who have iatrogenic manipulation—percutaneous lithotripsy or SP cystostomy tube presence—which may result in the entry of skin flora into the urinary system. When a gram-positive coccus is noted on stained urine or infected fluid, vancomycin is an appropriate empiric choice for sepsis of urinary tract origin, as both *Enterococcus* and *Staphylococcus* species are usually covered. With the emergence of vancomycin-resistant *Enterococcus* (VRE) and other more resistant gram-positive cocci, the advisability of providing coverage for such resistant pathogens pending culture and sensitivity data should be considered. Fungal organisms should be considered, especially in the diabetic patient and in the patient who has had extensive antibiotic therapy; fluconazole is an appropriate initial empiric coverage agent pending culture results. With the wide variations in organism sensitivity patterns among institutions and clinical environments, a close collaboration with the locally knowledgeable infectious disease specialists is advisable in selecting empiric and specific treatment regimens.

In addition to supportive care and antibiotic management, prompt drainage of the urinary tract is critical in certain conditions of urinary infection and urosepsis (52). When either upper or lower tract obstruction is suspected with urosepsis, prompt imaging of the urinary tract should be obtained, either noncontrast CT of the abdomen and pelvis, or renal and bladder ultrasound to exclude retention (50,53). Rapid decline in clinical status may ensue if there is a delay in instituting prompt drainage of an infected, obstructed system (54). I encourage our medical colleagues to practice the principle that the “sun never sets” on an obstructed, infected urinary tract. Uncertainty occasionally arises when there is incomplete obstruction, as evidenced by contrast passing beyond a stone on an imaging study, and the patient is clinically stable. The goal is to provide low-pressure drainage of the infected system because the patient can still deteriorate even when some urine is progressing beyond the point of obstruction. Whether to drain the upper tract through cystostomy and stent placement versus percutaneous nephrostomy, or the lower tract through IUBC placement or SP tube insertion, reflects a set of clinical judgments that varies from case to case, as discussed above. The available facilities and expertise, promptness of access to resources, coagulation status, and clinical instability and mobility all come into play in selecting the best approach to draining the urinary tract emergently. One major potential diagnostic pitfall occurs when a patient has complete unilateral upper tract obstruction with a negative urinalysis, as no urine from the obstructed system enters the bladder, and the urinary tract origin of sepsis is therefore not suspected. From the urologic perspective, routine abdominal imaging of septic patients with an unknown source is a wise approach, as it minimizes the potential for missing upper tract obstruction, potentially with a preventable poor outcome.

Certain specific infectious processes of the urinary tract deserve mention with regard to their relevance to the critical care provider (55,56). Emphysematous pyelonephritis and cystitis are infections of the kidney and bladder, respectively, which result in gas formation within the tissues (57,58). The presence of gas in the urinary tract may be due to gas-forming infection, previous instrumentation, or fistula. The clinical situation will usually lead to identification of the correct etiology. Gas-forming infections in the upper tract may represent a range of infectious processes: emphysematous pyelitis describes infection that results in gas within the collecting system, whereas emphysematous pyelonephritis describes gas within the renal parenchyma, which may progress into the perinephric space or other sites in the retroperitoneum. The most commonly seen organism in such infections is not the classic gas-forming anaerobes, but *Escherichia coli*, which may enter into a state of facultative anaerobic metabolism, especially in a diabetic when severe hyperglycemia is present. These patients may become severely ill and require aggressive resuscitation and sometimes drainage procedures or occasionally urgent nephrectomy; urologic consultation is essential. Emphysematous cystitis reflects the same bacteriologic basis and propensity for the diabetic patient as for the renal counterpart. IUBC drainage and aggressive antibiotic management will usually correct the process.

Acute papillary necrosis may also be seen in a diabetic due to microvascular renal disease that affects the vasculature of the renal papillae and pyramids, though other underlying conditions include excessive use of certain analgesics. When accompanied by infection, these patients behave like those with ureteral colic from calculous disease, as the sloughed papilla may obstruct the ureter, and will often require drainage and decompression of the urinary tract along with aggressive medical management. Sloughed papillae may dwell within the renal collecting system and undergo surface calcification, often resembling typical calcific disease, though the changes in the appearance of the calyces due to the sloughed papilla are indicative.

Renal and perinephric abscesses are important causes of urosepsis, and one must have a high index of suspicion in the setting of incomplete resolution of upper tract urinary infection with standard antibiotic regimens, prompting imaging to detect an undrained source of relapsing or persistent infection. CT scanning is significantly superior to ultrasound for imaging the perinephric space, and is preferable when an abscess is suspected. Small renal parenchymal abscesses not causing a septic picture may resolve with antibiotic treatment alone. Large parenchymal abscesses or perinephric collections usually require drainage, which in most cases can be carried out by a CT- or ultrasound-guided percutaneous approach. When multiloculated or an abscess inadequately drained by the percutaneous route is encountered, an open surgical drainage procedure may be necessary.

Acute prostatitis may be categorized by etiology—bacterial, abacterial—or clinical course and manifestations, acute or chronic (59,60). Acute bacterial prostatitis can present with a septic picture. Common symptoms include dysuria, frequency, urgency, chills and fever, elevated white blood count on CBC, and infected urine. Some urologists believe that urethral catheterization and instrumentation should be avoided in such patients due to concern of worsening sepsis. If the patient is emptying adequately, antibiotic administration is usually adequate without catheter drainage. If the patient is in acute urinary retention, bladder drainage is needed; one can proceed either with a gentle attempt at IUBC passage via the
urethra or with percutaneous SP cystostomy placement. My view is that urethral catheterization is usually preferable and is certainly less invasive. For patients presenting with acute prostatitis or other complex lower tract infection who do not respond appropriately to antibiotic therapy, or for those with suspicious findings on a digital rectal examination, prostatic abscess should be suspected. The findings of concern on digital rectal examination would include unusual tenderness and/ or an area of fluctuance on prostatic palpation. One should avoid an aggressive prostate examination on such patients, and it is generally ill advised to put significant digital pressure on the tender, acutely infected prostate to obtain a sample of expressed prostatic secretion as is often done in the chronic prostatitis patient. Acute prostatitis patients usually have infected urine and culture information from prostatic secretions is usually not necessary. Transrectal ultrasound or CT scanning of the pelvis will usually confirm the presence of a prostatic abscess, when present, and can also guide therapy by revealing whether the abscess cavity may be best drained through a transurethral, transperineal, or transrectal route. I usually prefer the transurethral approach if the cavity is abutting the prostatic urethral lumen. A transperineal drainage procedure can be performed under ultrasound guidance if the abscess is deep and a transurethral approach is deemed too risky. Unless the abscess has already started to drain spontaneously into the rectal lumen, this approach to prostatic abscess drainage is not favored. Acute infectious complications following transrectal prostate biopsy are well described and require aggressive antibiotic therapy and supportive care (61–63).

Acute infectious conditions involving the genitalia and perineum are important both with regard to the challenges sometimes faced in differential diagnosis, such as epididymitis versus torsion, trauma, or incarcerated hernia, and systemic management as in some conditions, for example, Fournier gangrene. Acute epididymitis or epididymo-orchitis may be due to standard enteric bacteria—more common in patients over 35 years of age and those with obstructive urethral or prostatic disease—or to venereal transmission of Chlamydial or Gonococcal infection. Mild epididymitis can be treated on an ambulatory basis with antibiotics. A fluoroquinolone often is acceptable if enteric infection is suspected; a tetracycline derivative is more appropriate if venereal transmission is likely, or a combination of two drugs if coverage for both entities is desired while awaiting culture data. Severe epididymo-orchitis is manifested by global enlargement of the hemiscrotal contents and loss of palpable anatomic landmarks, often with skin fixation and marked redness and tenderness. Such patients find it very painful to walk or stand, and may be best managed by hospitalization, bedrest, scrotal elevation, anti-inflammatory drugs, and broad-spectrum antibiotics until improvement is observed. Scrotal ultrasound examination may be useful for clarifying the diagnosis and excluding the presence of abscess formation, which may require surgical drainage and sometimes orchietomy, and late torsion with testicular necrosis, which may have a similar clinical appearance.

**Urologic Involvement in Complex Soft Tissue Infectious Processes**

Urologic participation in the management of such entities as perirectal abscess or Fournier gangrene is common. Fournier gangrene, or necrotizing fasciitis involving the genital and perineal soft tissues, may be idiopathic with no identifiable point of origin, or may be due to extension from primary rectal, urinary, intra-abdominal, or retroperitoneal processes. Diabetics are at increased risk for this disease. When there is genital, perineal, or groin involvement in such processes, several applicable management principles may be of value to the critical care provider or acute care surgeon. Such patients should be treated with broad-spectrum antimicrobial regimens that cover gram-positive and gram-negative aerobes and anaerobes, as polymicrobial infection is common. These patients require a combination of aggressive antibiotic therapy, metabolic and fluid resuscitation, and prompt and aggressive surgical debridement and drainage (see Chapter 85). These infectious processes can progress very rapidly, and delays in bringing the patient to surgery may result in loss of otherwise salvageable tissues, progression of sepsis, and increased mortality.

The surgical approach for this entity in our institution is based on the areas of involvement and typically includes the urology and general surgery teams in a close collaboration to address relevant areas of anatomic specialty expertise, with surgery performing proctoscopy and addressing debridement of involved abdominal wall, rectal, ischiorectal fossa, thigh, or buttock tissues, and urology performing cystoscopy as indicated and addressing genital and perineal debridement. The advantages of this combined specialty collaboration assists in functional and organ preservation, and subsequent reconstructive efforts. When an abscess or necrotizing process extends into the region of the perineum or genital soft tissues, incision or debridement of scrotal or penile skin and underlying dartos fascia may be necessary. In the scrotum, a dissection plane just superficial to the parietal tunic vaginals is established in order to keep this membrane, which surrounds the testes, intact. The testes are rarely involved in these soft tissue infections, and not directly exposing the testes to the wound will aid in subsequent wound management and avoid the pain and desiccation that occurs when the testis is exposed externally. On the penis, necrotic skin and dartos may be debrided up to the coronal sulcus when necessary, taking care to stay superficial to the deep (Buck) fascial layer of the penis, to avoid injury to the corpora and the dorsal neurovascular bundle, which lies in a wide band across the center on the top of the penis, and to the urethra, which lies ventrally. Fournier gangrene may occasionally arise from a urethral source, such as a perirectal abscess or perforated stricture or diverticulum. Debridement of urethral tissue should be avoided unless it is grossly necrotic, as a superficial exudate may create the appearance of marginally perfused tissue; such changes can be reassessed upon OR take-back and allowed to declare themselves further into the course of the disease. If the surgeon must enter the scrotal wall for drainage of a local abscess, it is best to avoid deep incision into the tunic vagina latum compartment to avoid preventable injury to the scrotal contents.

As general considerations for the patient with urosepsis, there is the potential that the patient’s hemodynamics and degree of severity of sepsis may transiently worsen following needed urinary tract drainage or manipulation. A low threshold to have such patients in the ICU is appropriate, even if they are not so critically ill that, initially, they are in need of ICU management. For example, in our institution, if we perform percutaneous nephrostomy insertion or ureteral stent placement in a patient with infection, an obstructing stone, tachycardia, and fever, especially when a pyonephrosis is encountered, we arrange overnight ICU observation to ensure
that any deterioration is promptly recognized and managed. When culture data become available, broad-spectrum empiric antibiotic regimens should be simplified based upon microbiologic identification and sensitivities. Tubes that are placed into the urinary tract to drain infected spaces must be appropriately secured to the patient to avoid inadvertent malposition or removal, and observed to avoid kinking or occlusion of outflow systems, which may prevent low-pressure drainage and exacerbate sepsis.

**UROLOGIC CAUSES OF RENAL FAILURE**

The urologist’s view of renal failure is usually focused on “postrenal” factors, as this is the setting in which we are typically consulted. At times, however, it is unclear whether a patient with acute renal failure (ARF) is suffering from an obstructive process, whether the process is remediable, and how best to approach therapy.

Assessment and management of ARF are covered in detail in Chapter 132. The urologist is typically consulted when there is suspicion or evidence that the state of renal failure is due to a mechanical or vascular etiology, usually manifested by significant oliguria and distention of some level of the urinary tract.

If an IUBC is in place in a patient with impaired urine output, palpation of the lower abdomen to detect bladder distention, ultrasound assessment of bladder volume, and/or irrigation of the catheter to ensure patency are appropriate initial steps. Management of catheter-related dysfunction is discussed in detail above. If uncertainty remains as to the appropriate positioning or function of an indwelling catheter, urologic consultation should be obtained.

If lower tract or bladder catheter malfunction has been excluded, one must exclude upper urinary tract obstruction. Renal ultrasound or noncontrast CT scanning is commonly employed for this purpose. The findings of hydronephrosis or ureteral dilatation raise concerns about the possibility of postrenal failure. It is important to appreciate that ureteral obstruction can exist without significant collecting system dilation in some cases, particularly if the obstructive process is of very recent onset. Patients with two normally functioning kidneys should not develop renal failure in the face of unilateral upper tract obstruction; in fact, complete obstruction of one ureter often causes little or no change in serum creatinine if the contralateral kidney is functionally normal. Unilateral upper tract obstruction involving a solitary kidney—or marked hypofunction of the contralateral kidney—may result in anuria and renal failure. In most of these cases, radiographic evidence of underlying inadequacy of the contralateral kidney is evident in that atrophy, long-standing obstruction with hydronephrosis and marked parenchymal thinning are present. In entities that can cause asymmetric and asynchronous development of obstructive uropathy—advancing prostate cancer with trigonal invasion, progressive pelvic lymphadenopathy, asymmetric retroperitoneal fibrosis with extrinsic ureteral compression—unrecognized loss of function of one kidney may result from obstruction without symptoms or a significant change in serum creatinine. Only when the remaining kidney becomes obstructed and renal failure ensues is the entire process recognized.

When evidence of upper tract obstruction is noted, one must expeditiously implement a strategy to determine definitively if postrenal obstruction is present, and choose the least morbid means of relieving it. The gold standard for such determination is to perform cystoscopy and retrograde pyelography. This procedure can be performed in the OR setting using static or fluoroscopic imaging capability, or at the bedside in the ICU. I have successfully performed flexible cystoscopy, retrograde pyelography, guidewire insertion and manipulation past a point of obstruction, and internal or externalized stent placement in the ICU. This approach is especially applicable in the hemodynamically unstable patient for whom movement to the OR may be hazardous. The newer digital x-ray units are ideally suited for such procedures, as the digital plate is placed beneath the patient once, allowing multiple images to be obtained and viewed on the monitor almost immediately. If an obstructed or tortuous ureter is encountered, the area of difficulty may often be navigated using a 5 French open-ended catheter through which an angle-tipped guidewire is advanced. Rotating the guidewire may allow passage across an area of ureter that is not possible using straight wires or catheters. Once a guidewire has been advanced past the complex ureter into the kidney, either an open-ended catheter or a double-J type internal stent may be inserted over the wire. Open-ended catheters may be tied to an IUBC for stability and attached to an external drainage appliance.

An alternative to achieving upper tract drainage cystoscopically is to have a percutaneous nephrostomy tube placed through IR techniques. It is important that the patient’s coagulation functions be normal when pursuing such an approach, and it is also important to verify, as best as possible that there is, in fact, upper tract obstruction present before introducing the risk of a percutaneous puncture. In the appropriate clinical setting, where there is certainty that upper tract drainage is needed, PCNL is an important option, and may be preferable to achieving drainage through lower tract instrumentation when dealing with urosepsis or challenging lower tract anatomy where manipulation may be difficult, as when gross hematuria, some cases of prior lower tract surgery, or permanent urinary diversion states exist. It is usually necessary for the patient to be prone on the radiology table to accomplish PCNL placement, and one must determine if such a position is safe or advisable. Respiratory compromise, recent abdominal surgery, or body habitus may create major challenges in placing the patient prone for such a procedure.

When lower or upper tract drainage is achieved in the setting of postrenal failure, one must observe the patient closely for transient worsening of urosepsis and for the possibility of pathologic postobstructive diuresis. Worsening of sepsis can result from instrumenting the infected urinary tract, and supportive measures may be necessary, including the institution of pressor support. Adequate hydration prior to urinary tract manipulation and provision of prophylactic antibiotics will minimize the risk of worsening sepsis with instrumentation. Pathologic postobstructive diuresis may occur when there is a major solute load and severe obligatory water loss occurs following relief of obstruction. This can be seen with lower tract or bilateral upper tract obstruction. Fluid and electrolyte monitoring and judicious fluid replacement may be necessary during the diuresis period.

Acute papillary necrosis may result in ARF. Papillary necrosis may develop as a gradually progressive, indolent process, recognized by the classic cavitary appearance of the renal calyces on contrast studies, or may present as a fulminant,
infectious course with urosepsis and obstruction from sloughed papillae. Relief of obstruction, treatment of infection, and supportive care are indicated.

Other entities for which urologic input may be valuable when ARF occurs include vasogenic renal failure, due to renal artery or renal vein thrombosis, and abdominal compartment syndrome–related renal failure. An important pitfall in diagnosis occurs when a patient presents with abrupt onset of flank pain, nonfunction of the ipsilateral kidney is noted in intravenous pyelography, and the presumptive diagnosis of renal colic from stone is declared. In fact, complete nonfunction is uncommon as an IVP finding from ureteral obstruction; more commonly, a persistent nephrogram with delayed excretion is observed. Complete nonfunction may be due to vascular compromise of the kidney either from primary arterial occlusion or renal vein thrombosis, which leads to microvascular occlusion and nonfunction. One should be suspicious of renovascular compromise whenever acute onset of flank pain occurs. Contrast-enhanced CT scanning is diagnostic, as the affected kidney will fail to opacify. When vascular compromise of the kidney occurs, urgent vascular surgical and IR consultation should be obtained to determine if immediate revascularization is feasible and warranted.

SUMMARY

Critical care issues in urology are many and varied. The intensivist must be familiar with the anatomic and physiologic factors that are relevant to urologic disease, and must have a low threshold to request urologic consultation when specialty expertise may be of value to the patient. Recognition of obstructive, infectious, and ischemic entities for which time-sensitive intervention is important is most essential for the critical care provider. In the postoperative setting, issues common to other surgical specialties are relevant to urology patients, and various specialty-specific problems may also arise, often related to renal dysfunction, the complexities of endoscopic and reconstructive surgery, and perioperative infection. Urologic residency training in the United States provides a strong background in critical care knowledge and skills, as all urology residents spend 1 to 2 years in general surgery and related specialties, including exposure to surgical ICU experience. The field of critical care requires an enormous breadth of knowledge and capability, however, and the practicing urologist and his or her patients may benefit greatly from the input and expertise of those specializing in the care of critical care patients. A close collaboration between these specialties greatly enhances the quality of urologic patient care.

Key Points

- Urologic surgery represents a diverse and complex set of interventions, involving upper and lower tracts and genital procedures, and open, endoscopic, laparoscopic, and robotic approaches. The intensivist must be familiar with the significant variety of management challenges and potential complications that may ensue when caring for urologic surgical patients in the ICU setting.
- Potentially immediately life-threatening issues in urology include severe bleeding and urosepsis. The intensivist must be able to rapidly assess the patient to exclude and when present, effectively manage these serious conditions. The magnitude and rate of urologic hemorrhage and the presence of a source of sepsis in the urinary tract must be expeditiously addressed.
- Minimally invasive approaches to urologic surgery have progressed significantly in recent years, changing the mode of presentation of urologic surgical complications and requiring a high index of suspicion for effective diagnosis. Laparoscopic and endoscopic surgery can result in significant morbidity which must be promptly diagnosed and treated.
- The combination of infection and obstruction of the urinary tract represents a surgical emergency, whether it occurs in the setting of an obstructing ureteral calculus, or an obstructed urinary drainage catheter in a colonized urinary tract. Rapid diagnosis with prompt decompression of the infected, obstructed urinary tract is essential to limit the morbidity and mortality of such surgical emergencies.
- Urologic trauma can occur in the setting of iatrogenic surgical procedures, or due to external violence. Urologic consultation should be obtained early when urologic trauma is suspected, so that the patient may benefit from the anatomic knowledge and management expertise of the urologist. Preventing further complications of the initial urologic injury, such as by avoiding injudicious urinary catheter placement when there is evidence of a pelvic fracture–related posterior urethral injury, is important in urologic trauma management.

References