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Urological Emergencies

A Practical Approach

Second Edition

Humana Press

Current Clinical Urology

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To Jack W. McAninch MD, FACS with esteem and appreciation for his contributions to the field of genitourinary trauma.

Preface

Urological Emergencies summarizes the optimal management of urgent and emergent urological conditions so that state of the art management of acute urological problems can be easily accessible in one volume. Since the publication of the first edition, evolution in areas of molecular testing, imaging quality, and guideline development has enhanced the ability to solve urological problems at the point of care. As with all medical advances, such progress is accompanied by the additional considerations of cost and potential harm from overdiagnosis and overtreatment.

The number one cause of death in young persons less than 44 years of age is accidental injury. The worldwide burden of disease due to trauma will increase immensely by 2020 as a result of wartime injuries and road traffic accidents in all parts of the globe. New chapters have been added to provide an overview of shock and resuscitation on the one hand, and a framework for addressing the growing problem through injury prevention on the other. Few nations have trauma systems in place that can rival our own. Thus mortality and disability due to trauma in nations with suddenly expanded vehicular traffic will be far higher than in North America, where such systems that have been shown to reduce cost and mortality. Severe renal injuries are immediately life threatening, and proper recognition of these requires application of appropriate criteria for staging and accurate imaging. Importantly, most of these injuries can be successfully managed through nonoperative trauma care. Lower urinary tract trauma, if unrecognized or mismanaged, can lead to early complications as well as permanent disability and dysfunction from disruption of essential neural, anatomical, and vascular structures of the pelvis. In all cases, the few remaining patients requiring emergent operative intervention will have severe and complex injuries.

Obstructive uropathy, kidney stones, and urosepsis are major sources of morbidity and mortality in the developing world. Mortality from acute infection is rare in the developed world yet the aging of the adult population and epidemic of obesity and type 2 diabetes mellitus will cause a dramatic increase in infectious, vascular, and obstructive urological emergencies in the United States. Differentiating between acute pyelonephritis and infection due to an obstructed ureter is essential for proper triage and successful treatment. Complicating such decisions are worldwide changing patterns of infection and the emergence of drug-resistant microorganisms. Accurate identification of urolithiasis and proper stratification to medical or surgical therapy based on CT now is possible. However, overuse of imaging with its

risk of ionizing radiation and secondary malignancies requires both individual and population level solutions.

Surgical error remains an irreducible feature of urological practice. Electronic health records, simulation and systems based approaches hold the promise to reduce complication rates. However, iatrogenic injuries remain an important cause of ureteral, bladder, and urethral problems. Lessons from trauma management and innovations in endoscopic techniques have allowed urologists to provide minimally invasive solutions in many cases. The appropriate supportive and medical care must be understood by those in direct contact with urological patients with stents, artificial sphincters, and indwelling catheters.

Congenital anomalies of the genitourinary tract carry a disproportionate risk of coexisting organ system abnormalities that require a highly multidisciplinary team approach to avoid death, permanent disfigurement, or irreversible cosmetic consequences. Despite prenatal sonography, many lower urinary tract anomalies are discovered only at birth. New concepts in the assignment of gender and the basis of gender, along with expanded genetic testing options, mean that the landscape for cases of ambiguous genitalia will continue to be complex and evolutional.

Urological Emergencies is organized by pathophysiology rather than organ system, allowing the reader to develop approaches to the care of patients with acute urological conditions based on mechanism of disease. Nationally and internationally recognized experts have provided up-to-date, evidence-based descriptions of the appropriate diagnostic and therapeutic considerations on topics of traumatic, infectious, obstructive, hemorrhagic, iatrogenic, vascular, and congenital urological emergencies. Relevant disease mechanisms and epidemiology are reviewed, necessary diagnostic testing recommended, and detailed medical, surgical, and endourological management approaches have been provided. It is hoped that the new edition of this text will continue to serve as a bedside resource for Urology residents, practicing Urologists, Emergency Medicine trainees and practitioners, and primary care providers without immediate access to urological consultation.

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Part I

Urogenital Trauma

The Science of Shock and Fluid Resuscitation

1

Eileen M. Bulger

Introduction

Shock is defined simply as inadequate tissue perfusion. This is an important definition as many think of shock as hypotension, but inadequate tissue perfusion can occur long before hypotension is evident. Inadequate tissue perfusion leads to anaerobic metabolism due to inadequate oxygen delivery and activation of the host inflammatory response, which can further exacerbate tissue injury and lead to the development of organ failure. Thus early recognition and management of shock is critical to preventing these sequelae. There are many compensatory mechanisms to preserve vital organ perfusion in the setting of hypovolemia. These include increased heart rate, increased sympathetic tone, and peripheral vasoconstriction. As a result, most patients will not manifest significant hypotension until they have lost more than 30 % of their blood volume. This is described as Class 3 shock. Class 1 shock involves a loss of 10–15 % of circulating blood volume (500–700 mL), Class 2 20–30 % (750–1,500 mL), Class 3 30–40 % (1,500–2,000 mL), and Class 4 >40 % (>2,000 mL). Cardiac output is dependent on both the heart rate and stroke volume. As a result, most healthy patients will compensate for decreased stroke volume by increasing tachycardia and this is usually the first sign of shock.

Etiology of Shock

The most common etiology of shock in the emergency setting is hypovolemic shock due to blood loss from trauma, spontaneous hemorrhage, or insensible fluid losses such as burns. Bleeding may be localized to the abdomen or thorax based on mechanism of injury but it is important to remember after trauma there are also significant losses due to hemorrhage from skin and extremity lacerations. There may also be issues of prehospital intravascular volume depletion due to prolonged extrication, long transport times, or delay in resuscitation in the field. Many medications used for general anesthesia cause peripheral vasodilatation and loss of sympathetic tone and thus patients with hypovolemia may become hypotensive only upon induction as they lose these compensatory mechanisms.

The second most common etiology of shock in the emergency setting is septic shock. The urological emergencies of Fournier's gangrene, upper urinary tract infection, and severe genital infection all may be associated with septic shock and are reviewed later in the text. Sepsis is defined as clinical signs consistent with the systemic inflammatory response syndrome (SIRS) together with definitive evidence of infection [1]. A diagnosis of SIRS includes two or more of the following: temperature

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>38 or <36 °C, heart rate >90 beats/min, respiratory rate >20 breaths/min or $PaCO_2$ < 32 mmHg, and WBC > 12,000 cells/mm^3 or <4,000 cells/mm^3 or >10 % immature forms. Severe sepsis is sepsis associated with organ dysfunction, hypoperfusion, or hypotension. Septic shock is sepsis with hypotension despite adequate fluid resuscitation. Septic shock can be divided unto early versus late septic shock. In the early phase, patients will be hyperdynamic with increased cardiac output, but inadequate tissue perfusion due to peripheral vasodilation and poor utilization of oxygen in the tissues. These patients are often hypovolemic as well and require initial fluid resuscitation prior to considering administration of vasopressors. In the late phase of septic shock, patients have impaired myocardial contractility and vasoconstriction, which can lead to progressive organ dysfunction. Exacerbation of the inflammatory response can also result in increased microvascular permeability which creates a "capillary leak" with loss of intravascular fluids into the interstitial spaces. As discussed in detail below, early goal-directed therapy for these patients has been associated with improved outcome.

Other less common causes of shock in trauma patients include cardiogenic shock, neurogenic shock, and hypoadrenal shock. Cardiogenic shock results from impaired cardiac function leading to inadequate cardiac output, usually as a result of chronic congestive heart failure or acute myocardial ischemia. Cardiogenic shock can also occur in the setting of compression of the venous outflow from increased intrathoracic pressure such as a tension pneumothorax. In this circumstance the patient is usually not hypovolemic. Neurogenic shock results from disruption of the spinal cord usually in the high cervical region resulting in loss of sympathetic tone and diffuse vasodilation. Finally, hypoadrenal shock may be due to acute adrenal insufficiency, which can result from adrenal infarction, withdrawal from long-term corticosteroid therapy, or critical illness-related corticosteroid insufficiency. For the purposes of this chapter we will focus on the management of the three leading causes of shock in the trauma patient, hypovolemic, septic, and cardiogenic, but it is important to remember neurogenic and hypoadrenal shock in the differential diagnosis especially for acutely injured patients.

Initial Management of Shock

The initial management of shock involves a high index of suspicion to allow early recognition of shock and initial fluid administration to begin to replenish intravascular volume and evaluate the patient's response to fluid challenge. The key is to quickly determine the etiology of shock in this patient so as to allow initiation of the treatment for the underlying problem. For example in a patient with hypovolemic shock the focus should be on finding the source of the bleeding and controlling that source. For a patient with septic shock, early administration of antibiotics and control of the source of the infection are paramount.

Patients can be grouped based on their initial response to a fluid challenge as responders, transient responders, and nonresponders. This distinction is important as it allows identification of patient who may require rapid surgical intervention. A responder is a patient who upon receipt of a fluid challenge normalizes their vital signs and does not show evidence of ongoing instability. A transient responder will show improved vital signs for a brief period of time but will again deteriorate suggesting an ongoing source of volume loss. Finally, a nonresponder will show no improvement in vital signs and likely represents a patient with significant hemorrhage or another etiology of shock such as cardiogenic or neurogenic. As a surgeon the focus must be on ruling out life-threatening hemorrhage in this group of patients. Patients who do not have evidence of ongoing hemorrhage may require invasive monitoring to further evaluate preload, such as monitoring of central venous pressure (CVP) or pulmonary wedge pressure, and cardiac function, such as measurement of cardiac output.

Management of Hypovolemic Shock

When hypovolemic shock is evident the treatment involves controlling any sources of hemorrhage and repleting fluid losses with crystalloid and blood products. There is no data to support colloids as the primary resuscitation fluid for trauma or surgical

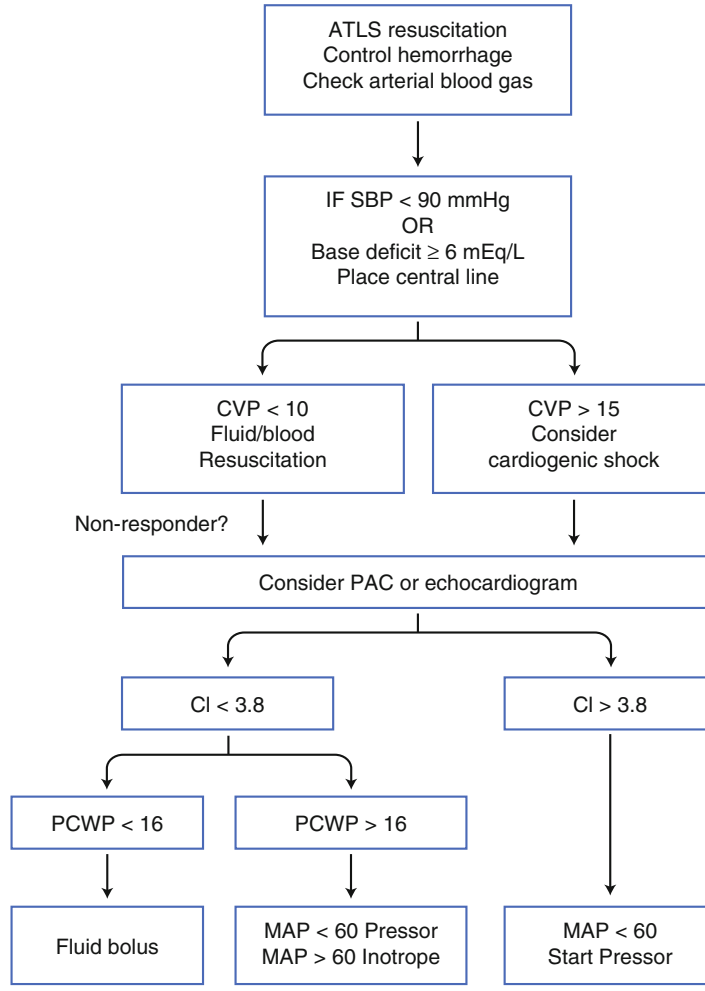

Fig. 1.1 Resuscitation algorithm for patients with shock after traumatic injury. *SBP* systolic blood pressure; *CVP* central venous pressure; *PAC* pulmonary artery catheter; *CI* cardiac index; *PCWP* pulmonary capillary wedge pressure; *MAP* mean arterial pressure (adapted from [28])

patients [2]. There is data to suggest that it is reasonable to limit volume resuscitation in the actively bleeding patient until surgical or angiographic hemostasis can be achieved. This is based on data from animal models that suggest that with a major vascular injury, rapid fluid administration can lead to increased blood pressure that may lead to increased hemorrhage in this situation [3]. Data from a clinical trial of patients with penetrating torso trauma suggests that very limited fluid resuscitation prior to surgical control of hemorrhage was beneficial [4]. This has also been shown to be the case in the setting of a ruptured abdominal aortic aneurysm [5, 6]. This approach is termed hypotensive resuscitation and implies that limited fluid is given to target a lower threshold for systolic blood pressure until hemorrhage control is achieved. There are also several animal studies supporting the use of small volume hypertonic saline solutions for resuscitation of hemorrhagic shock [7, 8]. However, recent clinical trials of prehospital resuscitation with hypertonic saline in severely injured patients have failed to demonstrate any benefit [9–11]. Figure 1.1 illustrates the resuscitation protocol advocated by the Inflammation and Host Response to Injury: Glue Grant Consortium [12].

There is also recent data to suggest that the development of coagulopathy occurs very early after injury in the setting of significant blood loss [13, 14]. This has led to the recommendation to consider early administration of blood products, especially fresh frozen plasma (FFP) in these

patients. Several retrospective studies from both civilian and military cohorts have suggested that patients requiring a massive transfusion who receive a higher ratio of plasma to packed red blood cells (PRBC) have a better outcome than those receiving a lower ratio [15–19]. Another recent study has also suggested that the ratio of platelets to PRBC may also play an important role [20]. These retrospective studies all suffer from survival bias, in that patients had to live long enough to get the higher ratio of products, but in general there is a sense that in selected patients minimizing crystalloid in favor of early administration of blood products with higher ratios of FFP to PRBC than traditionally used may be beneficial. A randomized controlled trial to determine the optimal FFP and platelet to PRBC ratio will likely begin enrollment in 2012. In the meantime, implementation of a standardized algorithm for the approach to as massive transfusion patient has been associated with improved outcome [21, 22]. Thus each institution should have a protocol, which can be activated as needed, to provide rapid availability of blood products to these patients. Finally, attention should be paid in these patients to avoid hypothermia, which has been clearly associated with increased coagulopathy and higher mortality.

In the setting of hypovolemic shock exacerbated by coagulopathy, acidosis, and hypothermia, damage control principles should be employed in the operating room [23]. The goals of a damage control procedure are to get control of the surgical hemorrhage and minimize GI contamination while minimizing the time in the operating room by delaying definitive repair and abdominal closure until after the patient has stabilized with correction of coagulopathy and rewarming to normothermia.

Management of Septic Shock

Recent data has suggested that early recognition of septic shock and aggressive management is associated with improved outcome. This is largely based on the study by Rivers et al. [24] that promoted an algorithm for early goal-directed therapy, which resulted in lower mortality. This includes early assessment of serum lactate to help identify patients with inadequate tissue perfusion, early administration of appropriate antibiotics, and early fluid administration and CVP monitoring to a goal CVP of 8–12 mmHg prior to initiation of vasopressors. The algorithm also emphasizes a targeted resuscitation to an $ScvO_2$>70 % (Fig. 1.2). Once fluid resuscitation goals have been met one can consider vasopressor support. The first line agent is commonly norepinephrine with additional vasopressin as needed.

Management of Cardiogenic Shock

Cardiogenic shock is less common but can be a source of sudden intraoperative shock in a patient suffering an acute myocardial infarction or pulmonary embolism. In this setting, one should rule out hypovolemia by administration of volume and consider early invasive monitoring to evaluate preload and cardiac function. When a patient has a sudden decline in the operating room it is also important to consider other problems that can cause acute hypotension such as a tension pneumothorax. If there is high suspicion for a pulmonary embolus the case should be aborted and if feasible anticoagulation should be considered. If this is not feasible, one may consider angiographic attempts to retrieve the thrombus and placement of an IVC filter to prevent additional thrombi. In these setting of cardiovascular collapse, surgical retrieval of the thrombosis may also be considered. If there is high suspicion for acute coronary ischemia, the case should be aborted and consideration made for cardiac catheterization. Most patients with cardiogenic shock will have adequate preload. Once this has been assured one should consider inotropic support if tissue perfusion remains inadequate.

Hemodynamic Monitoring

Most patients with shock especially those not responding to initial resuscitation efforts will require hemodynamic monitoring to guide the resuscitation. Data that can be useful to collect include markers of preload such as CVP or pulmonary artery wedge pressure, assessment of

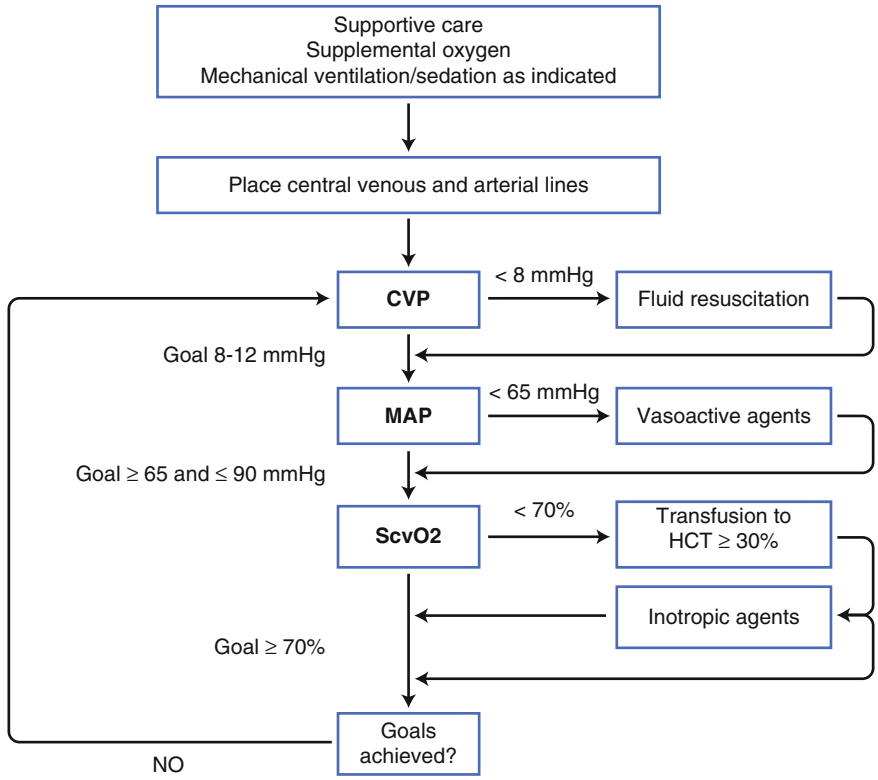

Fig. 1.2 Resuscitation algorithm for patients with septic shock. *CVP* central venous pressure; *MAP* mean arterial pressure; *$ScvO_2$* central venous oxygen saturation; *HCT* hematocrit (early goal-directed therapy, adapted from [24])

tissue oxygen delivery and utilization such as the central venous oxygen saturation and the cardiac output and systemic vascular resistance (SVR). Table 1.1 illustrates the changes one would expect in these parameters for each type of shock. There are a variety of monitoring devices now available to assess these parameters ad some authors have also advocated the use of bedside ultrasound or echocardiography as another means to assess preload.

Endpoints of Resuscitation

There has been much debate in the literature regarding the optimal endpoints to determine that an effective resuscitation has been achieved. Urine output is a good marker for restoration of renal perfusion and improved intravascular volume as long as there has not been a prolonged period of hypovolemia leading to acute renal failure, or underlying chronic renal disease. Urine output targets of 30 mL/h for adults and 1–2 mL/kg/h for children are accepted. More invasive monitoring allows for evaluation of preload based on venous filling pressures and cardiac output over time. As noted in the sepsis studies, many authors have advocated central mixed venous oxygen saturation as a target for resuscitation with a goal $ScvO_2 > 70$ %. Finally many authors target resolution of metabolic acidosis by trending either the arterial base deficit or the serum lactate level [25–27].

Summary

In summary, shock is simply inadequate tissue perfusion. The major etiologies for shock are hypovolemic/hemorrhagic, septic, cardiogenic, neurogenic, and hypoadrenal. The leading cause of shock in emergency patients is hypovolemic. Management of shock hinges on identifying the underlying cause and treating it (i.e., stop the bleeding) while pursuing

Table 1.1 Hemodynamic changes based on type of shock

Type of shock	CVP/ PCWP	Cardiac output	SVR	SvO_2
Hypovolemic	↓	↓	↑	↓
Early septic	↑↓	↑	↓	↑
Late septic	↑↓	↓	↑	↓
Cardiogenic	↑	↓	↑	↓
Neurogenic	↓	↓	↓	↓
Hypoadrenal	↑↓	↓	↓	↓

fluid resuscitation to restore intravascular volume. Resuscitation can be guided by hemodynamic monitoring and the clinical response to fluid resuscitation including improved urinary output and resolution of metabolic acidosis. Early recognition of shock is critical to allow intervention before there is significant organ injury.

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Injury Prevention

2

Thomas G. Smith III

Introduction

Unintentional injury is the leading cause of death among people 1–44 years of age [1, 2]. Furthermore, in this age group, injuries are the leading cause of physician contact resulting in more than 2.8 million hospitalizations and almost 30 million patient evaluations [3]. This burden is especially true in the youngest demographic, individuals between the ages of 1–34 [1]. The leading causes of death in this age group are motor vehicle collision followed by homicide. The economic cost of injuries is impressive as well. In 2005, an estimated $406 billion dollars in cost from medical- and work-related loss were absorbed due to evaluation, hospitalization, and deaths related to injury [2]. While trauma and emergency services personnel evaluate most of these patients, the urologist plays a role in the evaluation and management of patients with genitourinary injuries. In the United States, abdominal organ injuries resulted in 6.3 % of total injuries, whereas pelvic injuries resulted in 4.5 % [4]. Based on current US population data, approximately 15,000 persons would sustain renal injuries requiring hospital evaluation annually. Urethral and bladder injuries occur in approximately 10–15 % of pelvic fractures and the incidence of pelvic fracture in 2007 was greater than 67,000. Thus, an additional 6,000–10,000 urological injuries occur as a result of pelvic injury. Injuries to the genitourinary system are rarely life threatening, but the potential morbidity is quite high and results in significant changes in quality of life. Despite the fact that traumatic injury to the urinary system is a minor component of traumatic injuries, it is a prevalent disease. Recent literature suggests that the US trauma management system is strained and injury prevention activities do not constitute a significant portion of patient care, especially in these at risk individuals [5]. Historically, unintentional injuries were felt to be accidents or "acts of God" and therefore not preventable due to the seeming random pattern with which they occur. Only in the twentieth century did injury prevention and research develop a critical mass of strategies, programs, policies, and practices to become a recognized field of study [6]. The study of injury prevention seeks to understand the characteristics of injury through surveillance, research, and identification of risk factors. Targeting of these risk factors through well-developed and scientifically based prevention efforts determines which are effective and worth pursuing and which are ineffective and should be changed or discontinued. For the purposes of this chapter, all injury and prevention strategies will be limited to unintentional injuries rather than intentional (e.g., suicide and poisoning).

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Impact of Trauma

Trauma continues to be an important source of disease and disability in the United States. In 2009, over 177,000 people died as the result of unintentional injury and 2.5 million potential years of life were lost [1]. Based on the CDC National Center for Health Statistics in 2008, unintentional injury was the fifth leading cause of death (Table 2.1) [1, 7]. Unintentional injury is one of the top five causes of mortality in all age groups until the seventh decade of life (Table 2.2) [7]. It is the leading cause of death until age 44. Of unintentional injuries, motor vehicle collision or traffic-related fatality is the leading cause of death resulting in 38,000 deaths [8]. The third leading cause of death is unintentional falls and this results in 24,000 deaths annually [1]. In 2009, 29.6 million people sustained injury and the injury rate per 100,000 persons is 9,661. By age 15, unintentional injury related to motor vehicle collision is the third or fourth leading cause of nonfatal injury and overall resulted in 2.64 million emergency department evaluations in 2009. On a daily basis in the United States, tens of thousands of people (adults and children) are injured severely enough to seek medical care (Table 2.3). Of those, about 200 will develop long-term disability due to injury and 400 will die [9, 10]. On a global basis, 1.6 million people die from injuries each year and the incidence continues to increase [11, 12]. The ramifications of trauma go beyond injury or statistics of evaluation and death. Injury results in significant societal and personal monetary costs as well as personal disability. Injury, both intentional and unintentional, causes changes to the lives of affected individuals and their families. In addition to physical disability, they must adapt to changes in independence, decreased work ability, chronic fatigue, and interpersonal relationship changes from traumatic stress or brain injury. The lifetime cost of medical- and work-related unintentional injury in 2005 was 99 billion dollars [1].

Injury Defined

If injury is defined as a biomechanical event, the simplest definition is harm inflicted on a person due to the release and transfer of physical energy from an object. The release of a large amount of energy and its projection to the human body overwhelms the resistance mechanism. This energy transfer results in injuries when people, unstable environments, and hazards or objects converge. These three components, people, environment, and objects, are normally in balance with equal distribution and result in equilibrium of energy. When this distribution becomes unbalanced, there is a transfer of energy to a person and excessive energy transfer can result in injury. If this equilibrium is considered in terms of human performance, the balance of energy is expressed as performance and task demand [13]. Performance is defined as how well a task is completed. Task demand is defined as the effort required to complete an action. Depending on the complexity of the task, individuals are at greater or lesser risk for injury depending on their ability to equalize performance and task demand. These variables fluctuate over time and injuries occur when the performance does not meet task demand (substandard performance) or task demand exceeds performance ability. Performance and task demand can be analyzed graphically and the curves plotted. At each point the curves intersect, that intersection is referred to as an event (Fig. 2.1). Energy is unbalanced at these points and if this unbalanced energy is transferred from the object or environment to an individual, injury can result.

In the modern world physical energy comes in many forms including thermal, mechanical, electrical, nuclear, or chemical each of which is transferred to the human body in different ways [14]. Energy transfer is often a rapid process and due to its physical principals the results are predictable. Unfortunately, energy transfer and the resultant injury often have both immediate consequences and long-term sequelae [15]. The study of injury prevention seeks to evaluate and characterize this dual nature of injury, the immediate

Table 2.1 Ten leading causes of death by age group, United States—2008

	Age groups									
Rank	1–4	5–9	10–14	15–24	25–34	35–44	45–54	55–64	65+	Total
1	Unintentional injury: 1,469	Unintentional injury: 835	Unintentional injury: 1,024	Unintentional injury: 14,089	Unintentional injury: 14,588	Unintentional injury: 16,065	Malignant neoplasms: 50,403	Malignant neoplasms: 104,091	Heart disease: 495,730	Heart disease: 616,828
2	Congenital anomalies: 521	Malignant neoplasms: 457	Malignant neoplasms: 433	Homicide: 5,275	Suicide: 5,300	Malignant neoplasms: 12,699	Heart disease: 37,892	Heart disease: 66,711	Malignant neoplasms: 391,729	Malignant neoplasms: 565,469
3	Homicide: 421	Congenital anomalies: 170	Suicide: 215	Suicide: 4,298	Homicide: 4,610	Heart disease: 11,336	Unintentional injury: 20,354	Chronic respiratory disease: 14,042	Chronic respiratory disease: 121,223	Chronic respiratory disease: 141,090
4	Malignant neoplasms: 394	Homicide: 113	Homicide: 207	Malignant neoplasms: 1,663	Malignant neoplasms: 3,521	Suicide: 6,703	Suicide: 8,287	Unintentional injury: 12,782	Cerebrovascular disease: 114,508	Cerebrovascular disease: 134,148
5	Heart disease: 186	Heart disease: 97	Congenital anomalies: 161	Heart disease: 1,065	Heart disease: 3,254	Homicide: 2,906	Liver disease: 8,220	Diabetes mellitus: 11,370	Alzheimer's disease: 81,573	Unintentional injury: 121,902

Adapted from Miniño et al. [7]

Table 2.2 Ten leading causes of injury deaths by age group highlighting unintentional injury deaths, United States—2008

	Age groups									
Rank	1–4	5–9	10–14	15–24	25–34	35–44	45–54	55–64	65+	Total
1	Unintentional drowning: 443	Unintentional MVC—traffic: 385	Unintentional MVC—traffic: 532	Unintentional MVC—traffic: 8,647	Unintentional MVC—traffic: 6,358	Unintentional poisoning: 7,545	Unintentional poisoning: 9,496	Unintentional MVC—traffic: 4,137	Unintentional fall: 19,742	Unintentional MVC—traffic: 37,985
2	Unintentional MVC—traffic: 346	Unintentional drowning: 138	Homicide firearm: 143	Homicide firearm: 4,394	Unintentional poisoning: 5,946	Unintentional MVC—traffic: 5,446	Unintentional MVC—traffic: 5,866	Unintentional poisoning: 3,547	Unintentional MVC—traffic: 6,167	Unintentional poisoning: 31,116
3	Homicide unspecified: 192	Unintentional fire/burn: 111	Suicide suffocation: 141	Unintentional poisoning: 3,188	Homicide firearm: 3,612	Suicide firearm: 2,796	Suicide firearm: 3,789	Suicide firearm: 3,079	Unintentional unspecified: 4,769	Unintentional fall: 24,013
4	Unintentional fire/burn: 169	Homicide firearm: 44	Unintentional drowning: 123	Suicide firearm: 2,009	Suicide firearm: 2,357	Homicide firearm: 1,966	Suicide poisoning: 2,004	Unintentional fall: 1,809	Suicide firearm: 4,143	Suicide firearm: 18,223
5	Unintentional suffocation: 145	Unintentional suffocation: 41	Unintentional fire/burn: 64	Suicide suffocation: 1,653	Suicide suffocation: 1,752	Suicide suffocation: 1,855	Suicide suffocation: 1,772	Suicide poisoning: 1,164	Unintentional suffocation: 3,200	Homicide firearm: 12,179

Adapted from Miniño et al. [7]

Table 2.3 National estimates of the five leading causes of nonfatal injuries treated in hospital emergency departments, United States—2009

	Age groups									
Rank	1–4	5–9	10–14	15–24	25–34	35–44	45–54	55–64	65+	Total
1	Unintentional fall: 955,381	Unintentional fall: 631,381	Unintentional fall: 615,145	Unintentional struck by: 1,027,646	Unintentional fall: 791,629	Unintentional fall: 794,906	Unintentional fall: 928,315	Unintentional fall: 781,827	Unintentional fall: 2,202,024	Unintentional fall: 8,765,597
2	Unintentional struck by: 372,402	Unintentional struck by: 406,045	Unintentional struck by: 574,267	Unintentional fall: 917,167	Unintentional overexertion: 654,125	Unintentional overexertion: 564,548	Unintentional overexertion: 444,515	Unintentional struck by: 232,696	Unintentional struck by: 242,014	Unintentional struck by: 4,435,906
3	Unintentional other bite/ sting: 137,352	Unintentional cut/pierce: 118,440	Unintentional overexertion: 276,076	Unintentional MVC—occupant: 741,159	Unintentional struck by: 643,495	Unintentional struck by: 495,060	Unintentional struck by: 410,712	Unintentional overexertion: 217,605	Unintentional overexertion: 180,152	Unintentional overexertion: 3,207,877
4	Unintentional foreign body: 126,060	Unintentional other bite/ sting: 92,885	Unintentional cut/pierce: 118,440	Unintentional overexertion: 703,809	Unintentional MVC—occupant: 553,680	Unintentional MVC—occupant: 419,564	Unintentional MVC—occupant: 363,518	Unintentional MVC—occupant: 216,997	Unintentional MVC—occupant: 174,999	Unintentional MVC—occupant: 2,643,652
5	Unintentional cut/pierce: 84,095	Unintentional pedal cyclist: 84,590	Unintentional pedal cyclist: 118,095	Other assault/struck by: 451,123	Unintentional cut/pierce: 382,187	Unintentional cut/pierce: 308,801	Unintentional cut/pierce: 271,617	Unintentional cut/pierce: 171,584	Unintentional cut/pierce: 127,735	Unintentional cut/pierce: 1,997,752

Adapted from ref. [1]

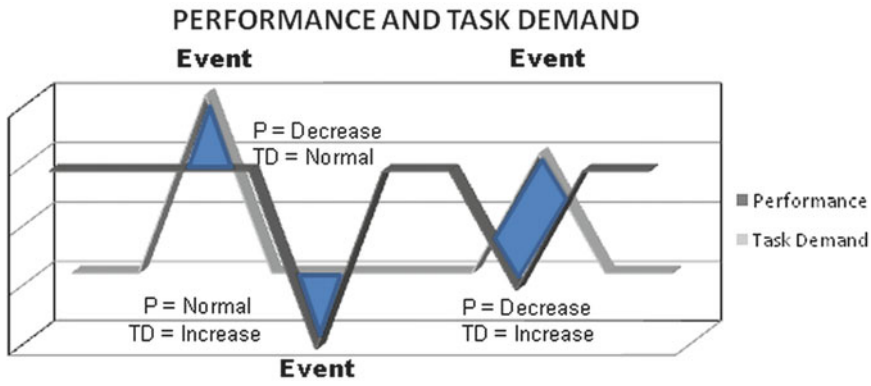

Fig. 2.1 Graphic depiction of performance and task demand (adapted from Martinez [13])

effects and chronic outcomes. This is especially important as injury is a unique disease that disproportionately affects a younger population and is not only a leading cause of death, but a cause of disability as well.

Injury Prevention: Historical Chronology

A fundamental change in the understanding of injury began when investigators first studied injury as a process or disease rather than a series of unrelated events. The scientific study of injury prevention began in the 1930s. Prior to this, victims of injury were thought to have suffered a random accident or were responsible for the injury due to carelessness or bad luck. However, this changed in the early twentieth century when researchers began to look at injury systematically. The first person to study injury as a cause and effect process was Hugh De Haven. De Haven was a physiologist who studied the kinetic forces related to crash or fall. In 1942, he published a study evaluating survival in falls from heights and found that if the transfer of energy could be changed or altered, the severity of the injury could be lessened [16]. He noted that the human body had a certain tolerance or resistance to transfer of mechanical energy. His theory that separation of the mechanical energy from the body lessened injury was the initial step in the study of injury prevention. With greater forces, the body sustains a greater injury; however, the body can sustain a certain amount of imparted energy without significant injury. The next major step in the science of injury prevention came from John Gordon who described injury in the epidemiologic terms of host (victim), agent (energy), and vector (environment) [17]. His description was important because it was the first time injury was viewed as a disease process and demonstrated how injury could be studied like other epidemiologic problems, namely infectious disease. The person most responsible for the discipline of injury prevention, however, was William Haddon. Haddon was the first director of the National Highway Traffic Safety Administration and in this capacity, his primary focus was road, traffic, and vehicular safety [18]. He approached injury systematically and studied injury as a biomechanical event due to the transfer of energy. He recognized, like De Haven, that if an individual can be separated from the energy transfer in the injury event, i.e., motor vehicle collision, then the damage inflicted can be diminished or eliminated. Haddon recognized that injury is the result of energy transfer and the effect of the uncontrolled energy is predictable based on physical laws. If energy is considered the vector and is predictable in its action, then the disease (injury) can be studied systematically. He went on to expand the epidemiological theory of Gordon and noted that each epidemiologic factor (host, agent, and environment) is affected by three constant and reproducible phases of injury: pre-event, event, and post-event [18]. By combining the epidemiologic factors of

Table 2.4 Haddon's matrix: motor vehicle collision injury prevention matrix

Phase	Host/human	Vector/vehicle	Environment
Pre-event	Driver experience	Condition of vehicle	Speed limits
Event	Seat belt use	Airbags	Highway design: guard rails
Post-event	Physical condition	Fire proof gasoline tanks	Emergency medical systems

Adapted from Maier [20]

disease with the sequence of events in trauma and injury (pre-event, event, and post-event) Haddon's matrix is created (Table 2.4). Haddon's matrix is important as it gives a framework for analysis and study of injury. In addition to the matrix, Haddon's other major contribution to injury prevention is his strategies for injury prevention. These ten strategies were the result of his observation that by separating injury into three phases of injury, several measures can be taken at each point to prevent injury. The basis of these strategies is to separate the agent or energy from the host.

Haddon's original ten strategies for injury prevention [18, 19]:

1. Pre-event
   (a) Prevent creation of the hazard.
   (b) Reduce the amount of the hazard.
   (c) Prevent the release of the hazard that already exists.
2. Event phase
   (a) Modify the rate of the release of the hazard from its source.
   (b) Separate, in time or space, the hazard being released from that which is to be protected.
   (c) Separate, by mechanical barrier, the hazard from that which is to be protected.
   (d) Modify the basic quality of the hazard to reduce the energy released.
   (e) Make what is to be protected more resistant to damage from the hazard.
3. Post-event phase
   (a) Detect and counter the damage already done by the environmental hazard.
   (b) Stabilize, repair, and rehabilitate the damaged object.

Haddon's ten strategies for injury prevention and the subsequent matrix are the basis for most injury prevention programs and ongoing prevention studies.

Injury Prevention Strategies and Analysis

Despite the fact that the source of injury is a fast acting force, injury occurs over a continuum. Injury is studied by breaking this process into the three phases proposed by Haddon. In the pre-event phase, energy has not yet been released or transferred to cause injury and strategies applied at this point are often referred to as primary prevention. At this point in the injury continuum, the strategies seek to prevent injury from occurring by changing susceptibility or inhibiting exposure. Examples of primary prevention include driver's education classes or sobriety checkpoints. During the event phase, the energy is transferred to the host and strategies at this point are referred to as secondary prevention. These factors tend to attempt to reduce energy transfer to the host either by early detection or early treatment. Examples of secondary prevention include seat belts and automobile air bags. The final phase, post-event, energy has been transferred and strategies here are referred to as tertiary prevention. Factors applied here seek to minimize injury and the focus is on restoring function of the individual or limiting the resultant disability. Examples of tertiary prevention include emergency medical services, designated trauma centers, and specialized rehabilitation centers.

In Haddon's matrix each component of the epidemiologic triangle (host, agent–vector, and environment) has application for each of the phases of injury. Thus, the host (human) can be impacted in each of the phases: pre-event—impaired capabilities, event—injury tolerance of the body, post-event—degree of injury sustained [18]. Haddon's ten general strategies for injury prevention provide an outline for the logical and systematic evaluation of injury events. This framework can be termed an options analysis [13].

In this context, a problem is approached by evaluating each strategy as it applies to the problem and generating the most likely preventative actions at each phase of the injury event. A unique aspect of the options analysis is that it does not require an in-depth understanding of the factors responsible for the injury as the analysis is directed at preventative strategies not elimination of the problem. The end result of the application of an option analysis is countermeasures to injury or preventative strategies. Prior to implementation, each prevention strategy or countermeasure must be evaluated in terms of cost, practicality, and effectiveness. In using Haddon's outline for development of injury prevention strategies, the real world application is that each point is not always applicable to each problem. However, the outline allows for thoughtful analysis of a problem and in this process several actionable strategies to the problem emerge.

Approaches to Injury Prevention

Identification of practical strategies for injury prevention is only half of the work; the other half is the implementation of these identified measures. The methods of implementation fall into one of three categories, known as the three "E's": education, enforcement, and engineering [20]. These three categories can be divided into two types of intervention: active and passive. Active interventions necessitate a change in the behavior of the individual and require performance of an act such fastening a seatbelt. Passive interventions do not require any action by the host (person) and typically these preventative measures are built into the design of the agent (vehicle). The host will receive protection simply by use of the object or vehicle (agent) in the environment.

Education: Education is the easiest strategy to implement and the most common method used in injury prevention. The idea behind education is that once the host or person is given information, knowledge, or training they will process and store this information and use it to reduce their risk of injury. Education is an active intervention that seeks to change behaviors and protect the host in this fashion. However, the person must be able to understand, process and apply the knowledge to gain benefit. The most effective education programs have ongoing evaluation for changes in behavior and outcome. This has not always been the case and without analysis and appropriate implementation, education programs are less successful or even completely ineffective [21]. Furthermore, to ensure long-term success, education strategies must have a plan for long-term effectiveness otherwise the initial effort loses impact. Despite this, education is a simple, powerful tool that can disseminate information effectively to large populations. Additionally, in today's society, social media and marketing can inform large segments of society and effectively change social attitudes, ultimately creating popular support for injury prevention strategies.

Enforcement: The second active intervention in the three "E's" is enforcement. These are legal and administrative directives enacted to effect injury prevention strategies. The legal aspect of enforcement includes both legislative efforts to create laws and government enforcement of the laws. These are often more effective than education because implementation is mandated rather than suggested. However, the legal and administrative directives come with many limitations and restrictions [22].

To begin with, the population at large must recognize and agree that the problem merits legislation and passage of a law. In American society, people favor legislation if they perceive that it will protect them or prevent someone from injuring them, but oppose something that limits their rights including the ability to harm or injure oneself. For example, the public favors laws restricting drunk driving but does not approve of mandatory safety belts or use of motorcycle helmets [13]. Typically, Americans support laws that affect other people and oppose laws that affect them personally. The major challenges to legislation and legal directives are cost and loss of personal freedom [23]. One hurdle with respect to cost is convincing individuals that despite the direct cost they may incur due to legislation, the treatment and rehabilitation of preventable

injuries is an expense shared by the larger population in the form of taxes and public healthcare support. When considering loss of personal freedom, three factors reduce the effectiveness of laws and legislation: exemptions, enforcement, and punishment [24]. Exemption detracts from the law by creating ambiguous enforcement rules or altering the intent of the law. Seat belt laws exemplify this as many states do not allow for primary enforcement of these laws but rather citation if a driver is stopped for other reasons [25]. In this scenario, primary enforcement of seat belt laws is exempted. Laws that are enforced based on age are an example as well. Compliance with laws and directives has a direct correlation to enforcement and punishment. If the population does not believe that enforcement is likely then there is no incentive to comply with the law. The easiest laws to enforce are laws that are easy to for law enforcement observe, i.e., speed limits and helmet laws. Speed limits are easy to enforce as the top speed is posted and laser or radar speed detectors are used to directly measure a vehicle's speed. Punishment for violation of laws improves compliance with laws as well. If violation of a law does not result in punishment, fewer individuals will comply with the law because there is no fear in punishment. An important legal phenomenon, however, is that more severe punishment lessens the punishment or conviction rate because a severe punishment necessitates greater strength of evidence due to the severity of the penalty [13].

Engineering: The final E is engineering. Engineering strategies are considered passive actions. Passive actions do not require any participation on the part of the host. A unique aspect of engineering is that it is a strategy that is effective in the event phase of an injury, i.e., airbags in an automobile. Since no active participation is required from the individual, engineering is thought to be the most effective injury prevention strategy. However, despite the fact that this is a passive intervention, engineering faces opposition not unlike legislation: complaints of loss of personal freedom and benefits which do not outweigh the costs [26]. American society continues to evaluate injury prevention and other social efforts with the viewpoint that safety should be a design element that does not limit the performance of things we use. However, it is apparent that advances in engineering make many potential hazards, especially motor vehicles, safer [14]. In addition to the event phase, engineering can impact the post-event phase as well. Automobiles are designed to reduce fires at impact, sensors in automobiles can alert medical care, and trauma systems can remotely monitor the injured person (host) in transit. Again, these benefits of engineering are passive interventions that do not require participation of the host [18].

Evaluation of Injury Prevention Programs

Injury prevention programs are only as successful as the results of their interventions. These programs should be evaluated at two points: process and outcome. Process evaluation is an ongoing step to provide and obtain feedback for the intervention. If the outcomes from an injury prevention program are not equivalent to those envisioned during the design of the program, the end result cannot be ensured. Outcome, ultimately, is the most important measure of any injury prevention program. The goal of a program is to reduce or impact the incidence or severity of specific injuries. Often it is necessary to measure the outcome in stages and to look for changes in behavior, which ultimately will affect the incidence of the injury. An example is the increase in number of helmets worn by motorcycle riders after passage of helmet laws or legislation [27]. While there is not an immediate change in brain or spinal injury following these actions, if the observed number of helmets worn increases, then the assumption can be made that ultimately, brain and spinal injury due to motorcycle collisions will decrease. Additionally, outcome can be measured with a series of questions: Have attitudes changed? Has behavior changed? Is there a correlation between favorable outcome and behavior change? [13]. Ultimately, if the first two questions result in positive answers but the last question, outcomes, is unchanged then the program is

not successful. The programs which have all three questions answered affirmatively usually require fewer, ideally one or two, major but simple changes in behavior.

Priority Areas for Genitourinary Injury Prevention

Urologists have many opportunities to impact the field of injury prevention through investigation, research, and public education merging our knowledge of the genitourinary system with the three "E's." The primary "E" for urologists is education. The American Urological Association has created a model in the male health check list [28]. The male health checklist is divided into two sections, urology specific and related health categories and these are subdivided into four age groups. With this framework, urology-specific and related health injury risks can be created and stratified by age. Organ- and age-specific injury databases will assist with identification of potential injury causes and preventative measures can be developed from these data. The second "E," enforcement, is the most underutilized "E." Two applicable scenarios for prevention are sports-related and military combat-related genitourinary injury. Presently, there is very little policy or rule with regard to genitourinary injury and its prevention through enforcement or penalty. The only sport, either professional or amateur, to require genitourinary protective equipment is Little League baseball [29]. Their rules require players to wear athletic supporters but not necessarily a protective cup-type device. The recent military literature has considerable documentation showing the decrease in genitourinary injury with the use of body armor [30–32]. In the current conflicts in Iraq and Afghanistan, more soldiers are injured by improvised explosive devices than missile or other blast injury [33]. Recently, explosion resistant undergarment had been created using flexible armor plates and Kevlar woven into the fabric. Troops are now deployed with both body armor and external genital armor/protective garments. No official policy exists requiring soldiers to wear either armor or protective garments despite this evidence. The primary limitation in both civilian and military realms is inspection. Any external protection is easy to inspect, however, identification of undergarment protection is time-consuming and fraught with privacy issues. The third "E," engineering, is an emerging area in which we as urologists are becoming involved. Blunt injury is the most common form of genitourinary system injury and the leading cause is motor vehicle collision. As the field of injury prevention matures, centers of excellence, such as the Harborview Injury Prevention and Research Center, are emerging and contributing to this "E." Two recent publications have evaluated both sources of injury in the passenger compartment of an automobile as well as the effectiveness of passive protective devices, i.e., airbags [34]. In evaluating sources of injury, the steering wheel, central console, and seatbelt buckles are the key causes of renal injury in frontal and side impact collisions [35]. With this knowledge, engineers and designers can modify the passenger compartment layout and passive safety equipment accordingly. Furthermore, airbags may both be a protective device or source of injury based on vehicle speed. Changing the airbag deployment sensors and calculating for vehicle speed can improve the protective effect and reduce the injury component of these safety devices. Injury prevention has great importance in the era of healthcare reform and cost containment. Focusing on more minor injuries will impact a larger segment of the population as a greater number of persons sustain minor injuries annually and require medical evaluation while severe injuries, although more morbid are less common. The urologist is in a position of educator and simple tools such as an injury checklist and prevention strategies are the easiest to implement. Continued legislative focus, such as the American Urological Association task force on Urotrauma, can bring about reasonable changes in military enforcement and improved engineering. Finally, continued efforts to identify injury sources and partner with industry are one way urologic injury prevention improves through engineering.

Conclusion

Injury prevention programs and interventions are beneficial at the individual and societal level. However, injury prevention requires a multidisciplinary team work and often the assistance of nonmedical or first responder persons. Injury prevention has developed into a discipline combining elements of medical care, epidemiology, and biomechanical sciences. All of these aspects are critical both to the evaluation and strategy of injury care but also the implementation and advertisement of the program. Haddon's well established matrix and ten prevention strategies (based on the pre-event, event, and post-event phase of injury) provide the framework for the conception for all of these activities. Physicians play a critical role in this process as well as they are well positioned both as injury data collectors, care givers following injury events and educators to patients and the public for prevention strategies. By properly embracing this leadership role, physicians contribute to safer communities through reduction of injury at the local, state, and national level.

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The Current Management of Renal Injuries

3

Bryan Voelzke

Introduction

The kidney is the most common genitourinary structure involved in trauma and the second most common visceral organ injured in blunt abdominal trauma. The majority of renal injuries are low grade [1] and clinical management has evolved as a result of improved radiographic techniques, advancements in hemodynamic management, validated renal injury scoring systems, and accumulated interest in genitourinary trauma. Nonoperative approaches are safe and effective within current guidelines. However, some injuries will require surgical and/or invasive intervention to maximize patient outcome and minimize morbidity. This chapter reviews the evaluation, management, operative technique, and outcomes after renal injury.

Classification and Incidence

The American Association for the Surgery of Trauma (AAST) Organ Severity Score for the kidney (Fig. 3.1, Table 3.1) [2] was originally described in 1989 as a means to facilitate clinical research and has since been validated as a powerful predictor of clinical outcome and the need for operative intervention and nephrectomy after renal trauma [3, 4]. A recent report recommended revision of the renal AAST staging system [5]. However, to date no publications have prospectively validated the revisions, and thus trauma centers should continue to use the currently accepted staging system.

The vast majority of renal trauma is secondary to blunt injury (Table 3.2) [6]. Retrospective reviews of overall adult trauma show the incidence of renal injury to be 1.13–2.8 % with nephrectomy rates in this group of 0.8–7.34 % (Table 3.2) [7–10]. The majority of renal trauma occurs in younger men; one population-based study reports 72 % of patients are between 16 and 44 years old [8]. In a series of 2,024 blunt trauma patients, only 81 (4 %) had grade III or higher renal injuries [9], a finding supported by other analyses [11, 12]. A separate retrospective review from San Francisco General Hospital found that only 2.4 % of 1,363 renal injuries presenting to a major trauma center required surgical intervention, emphasizing that most blunt renal trauma is managed nonoperatively [13].

Blunt renal trauma is less commonly associated with concomitant injuries than penetrating renal trauma; however, as blunt renal injury grade increases so does the risk of associated injury [6, 10]. Major force is required to affect the kidneys in their protected retroperitoneal location, accounting for injury to contiguous organs. In addition, injury to surrounding structures (e.g., fractured ribs causing renal parenchymal lacerations) and mechanism of injury (e.g., deceleration injury causing renal pedicle disruption) are key aspects of the history and physical examination that

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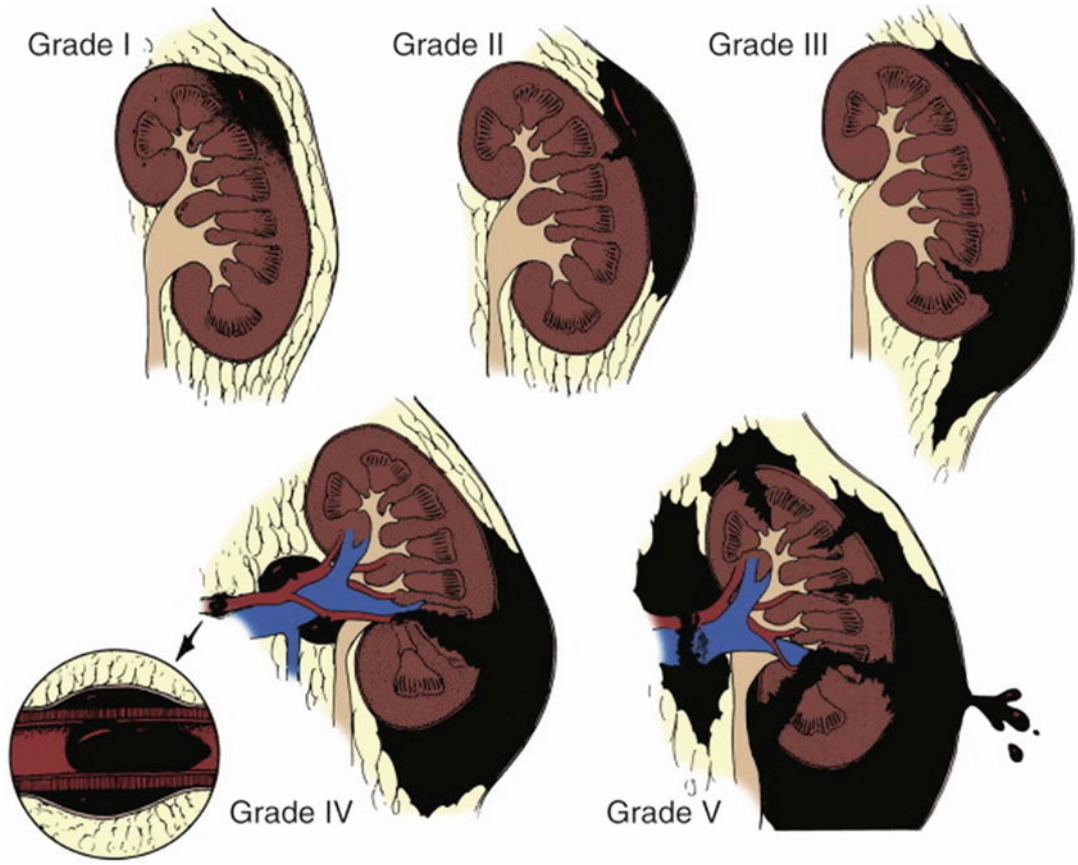

Fig. 3.1 American Association for the Surgery of Trauma (AAST) Organ Injury Severity Score for the kidney (from Campbell-Walsh Urology, 10th Ed., Volume 2, Upper Urinary Tract Trauma, p. 1171, Copyright Elsevier, 2012; with permission)

should alert physicians to potential renal trauma. Motor vehicle collision kinematics also provides predictors of renal injury. Blunt renal trauma results from acceleration into the seat belt or steering column in frontal crashes and vehicle side panels in lateral impact collisions [14, 15].

Penetrating renal injuries are predominately secondary to gunshot wounds (GSW) with stab wounds a distant second in etiology (86 % vs. 14 % in one large retrospective study [16]). Penetrating injuries are associated with adjacent organ injury (94.6 % in one study [16]) and have a more advanced grade, leading to higher rates of surgical exploration. Among 230 patients with penetrating trauma, 154 (67 %) had grade III or higher renal injury, compared to the 4 % after blunt trauma, emphasizing the more serious nature of penetrating renal injuries [9]. The greater preponderance of high-grade injuries after penetrating trauma justifies the imaging of all patients with suspected renal injury after stab wounds and firearm injuries.

Initial Assessment

Mechanism of injury, urinalysis to identify hematuria, and hemodynamic status are the most important factors to consider in renal injury evaluation. Of the three factors, early hemodynamic stability is the most vital variable, indicating the need for radiographic imaging to delineate the extent of trauma and enable a more focused approach to initial management. With this in mind, Miller and McAninch reviewed the records of approximately 2,200 patients to evaluate the

Table 3.1 American Association for the Surgery of Trauma (AAST) Organ Injury Severity Score for the kidney

Grade[a]	Type	Description
I	Contusion Hematoma	Microscopic or gross hematuria, urologic studies normal Subcapsular, nonexpanding without parenchymal laceration
II	Hematoma Laceration	Nonexpanding perirenal hematoma confined to renal retroperitoneum Perenchymal depth of renal cortex <1.0 cm without urinary extravasation
III	Laceration	Perenchymal depth of renal cortex >1.0 cm without collecting system rupture or urinary extravasation
IV	Laceration Vascular	Parenchymal laceration extending through renal cortex, medulla, and collecting system (positive urine extravasation) Main renal artery or vein injury with contained hemorrhage
V	Laceration Vascular	Completely shattered kidney Avulsion of renal hilum that devascularizes kidney

Described by Moore et al. [2]
[a]Advance one grade for bilateral injuries up to grade III

Table 3.2 Demographics of renal trauma

	Series			
	[5]	[6]	[7]	[8]
N	154	6,231	2,254	742,774
Renal injury (%)	2.8	1.2	n/a	1.13
Blunt (%)	93.5	81.6	89.8	81
Penetrating (%)	6.5	18.4	10.2	19
Renal explorations (%)	n/a	13	7.4	10.6
Nephrectomy (%)	3.8	7	0.8	7.34

Table 3.3 Indications for radiographic imaging of suspected renal trauma

Adult penetrating abdominal trauma
Adult blunt abdominal trauma and gross hematuria
Adult blunt abdominal trauma, microhematuria, and shock (SBP < 90 mmHg)[a]
Pediatric trauma
High index of suspicion[b]

[a]Vital signs recorded in the field are most sensitive
[b]Deceleration injuries, high-speed motor vehicle accidents, multiple abdominal injuries

criteria for radiographic imaging of renal injuries [9]. They concluded that adults (>16 years old) with blunt renal trauma, microhematuria (>5 RBC/HPF), and absence of shock (SBP > 90 mmHg) without high index of suspicion for renal injury could be spared radiographic imaging. Only 3/1,588 patients with blunt renal injury, microhematuria, and SBP > 90 mmHg had significant renal injury, and these injuries were discovered during imaging or exploratory laparotomy for concomitant injuries. Table 3.3 details the indications for radiographic imaging after abdominal trauma. Of note, the first systolic blood pressure obtained by the paramedics should be the parameter used as this value correlates most accurately to the grade of the injury. Urinalysis for microhematuria should be performed early in the initial workup prior to fluid boluses, avoiding the decrease in sensitivity with hemodilution. Lastly, patients with significant deceleration injuries (i.e., following a fall from a great height) may require imaging as 30 % of renovascular injuries will not be associated with gross or microscopic hematuria [17]. A heightened degree of suspicion is necessary in these circumstances to avoid missing a ureteropelvic junction injury or renal artery dissection (Fig. 3.2).

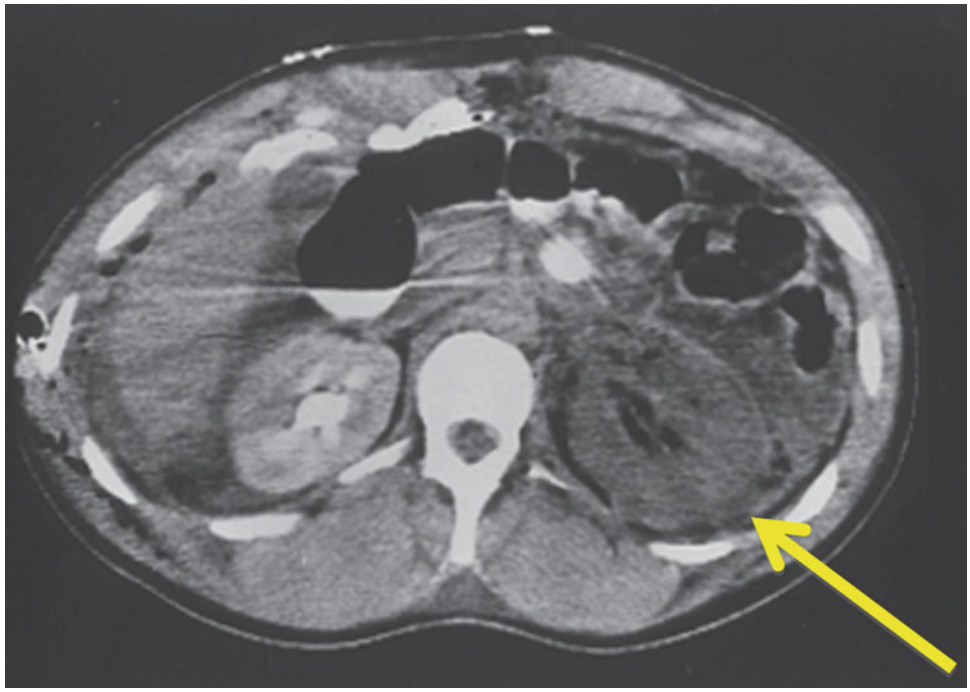

Fig. 3.2 Renal deceleration injury (AAST grade V) following fall from a two-storey building. There is a left renal artery dissection resulting in absence of arterial perfusion (*arrow*). There is a classic "rim sign" from surrounding non-hilar artery flow. The kidney was managed in a nonoperative fashion

History and Physical Examination

A careful history and physical examination provides vital information about possible injuries, particularly when hemodynamic instability limits detailed radiography. Determination of entry and exit wounds allows an educated guess at internal trajectory and possible organ involvement. Deceleration injuries, such as falls from height and high-speed motor vehicle collisions, and direct blows to the flank should raise suspicion of renal involvement. Stab wounds are evaluated for size, shape, and entry point. Penetrating trauma to the anterior axillary line may damage important renal structures such as the renal hilum and pedicle, while trauma to the posterior axillary line more often results in parenchymal injuries [18]. Advancements in weapons and ammunition require clinicians to consider not only the velocity of GSW but also factors such as bullet shape (e.g., blunt or narrow), type (e.g., hollow point, exploding, frangible), and caliber [19]. All of these factors help the clinician predict the likelihood of renal injury, both direct and collateral.

Importance of Hematuria

Determination of microscopic hematuria can be performed via dipstick or microscopic urinalysis. Dipstick analysis had a 97.5 % specificity and sensitivity when compared to microscopic urinalysis in one large study of patients after blunt renal trauma [20]. The degree of hematuria does not predict the degree of renal injury in either blunt or penetrating abdominal trauma, and the significance of hematuria varies [21]. An analysis of 113 patients with grade IV renal injuries after blunt and penetrating trauma found that hematuria was present in 88 % of patients (63 % gross vs. 25 % microscopic) [22]. Four percent did not have gross or microscopic hematuria, while the remaining 8 % had no urinalysis

prior to operative intervention. A separate study found that gross and microscopic hematuria was absent in 58 % of GSW and 54 % of stab injuries reinforcing the need for radiographic imaging after penetrating abdominal trauma regardless of hematuria [16]. Patients with injury to the ureteropelvic junction may not have hematuria in up to 50 % of cases, supporting the need for radiographic imaging if suspicion for injury persists [23].

Radiographic Evaluation

Computed tomography (CT) is the gold standard for visceral imaging after blunt abdominal trauma and provides excellent anatomic detail that is superior to previously used imaging techniques such as intravenous pyelography [17]. The ability to assess contrast extravasation and evaluate vascular injuries has improved the decision-making process for nonoperative management vs. immediate renal exploration. CT imaging of the kidneys is essential for adequate assessment of the kidneys and ureter. The first (arteriovenous) phase visualizes the kidneys in the nephrogram phase of contrast excretion, allowing detection of arterial extravasation (typically 80 s after contrast administration). Delayed (or excretory) phase imaging should be done in stable patients 10 min later to examine the renal collecting system for injury and ureteral integrity [24]. A repeat CT scan 48–72 h later to assess for renal injury progression is recommended for select high-grade renal injuries, when clinically appropriate. For example, reassessment of a collecting system laceration (AAST grade IV) 48 h after initial nonoperative management determines if urine leakage is persistent or worsened. The findings should influence the treating physician to place a ureteral stent and urethral catheter if the urine leakage has progressed or is persistent. Such an early intervention could reduce progression to a symptomatic urinoma. In contradistinction, a repeat CT scan 48 h after diagnosis of a blunt vascular segmental renal injury may not be necessary during the index hospitalization.

The utility of the one-shot intraoperative intravenous urogram (IVU) is a controversial topic among urologists and general surgeons; however, it is a vital part of the evaluation when CT is contraindicated by the need for immediate laparotomy. In this setting, the main role of one-shot intraoperative IVU is to identify a normal contralateral kidney prior to impending renal exploration. Additionally, one-shot IVU has allowed renal exploration to be avoided. In a retrospective study of 50 patients, the one-shot intraoperative urogram allowed safe observation in 16 (32 %) patients [25]. IVP is performed by venous injection of 2.0 mL/kg of contrast material with one-shot urogram 10 min later. It should be noted that massive fluid resuscitation, peripheral edema, and significant hypotension can limit radiographic outcome [6].

Other radiographic modalities have been proposed in the setting of renal injury including ultrasound, retrograde pyelography, radionuclide scintigraphy, and renal angiography. Ultrasonography in the emergency department is an efficient, noninvasive modality to evaluate for hemoperitoneum; however, it has been shown to miss important renal injuries [26]. Retrograde pyelography is useful for determining the presence of ureteral or renal pelvic injury (i.e., nonvisualization of ureter or renal pelvis on delayed CT images) when CT cannot provide definitive diagnosis. If concern persists, then surgical exploration with repair is recommended [27].

Radionuclide scintigraphy provides little additional information regarding renal imaging during index hospitalization; however, it is an important study for high-grade renal injuries 2–3 months after renal injury. The MAG3 renogram is useful for the evaluation of renal function when conservative management has been elected for high-grade renal injuries or to document renal function after major renal reconstruction. The results can guide future management decisions and provide important patient counseling regarding final renal function to the previously injured kidney.

Renal angiography is diagnostically and therapeutically imperative for select cases. Precise determination of renal vascular injury can facilitate renal embolization in a hemodynamically

stable patient with persistent renal hemorrhage after nonoperative treatment. In the acute setting, angiography can evaluate for renal artery dissections when there is nonvisualization of the kidney. Renal embolization has also proved useful for treatment of secondary hemorrhage due to renal pseudoaneurysm and arteriovenous fistula [28, 29]. The initial success of renal angioembolization is not definitive; hence additional renal interventions may be necessary [30].

Management Options

Nonoperative Management

In the past decades, nonoperative management of renal injuries has gained momentum as a viable management strategy [31]. Consensus agreement supports nonoperative management of low- and intermediate-grade renal injuries (AAST I–III) [6]. When initial nonoperative therapy is not successful in controlling hemorrhage, superselective renal angioembolization can be utilized in an effort to avoid open surgical intervention. National analysis of angiographic utilization has shown this technique to be a useful adjunctive therapy [30]. Regarding AAST grade IV renal injuries, the injury pattern can involve a collecting system injury or segmental vessel injury. Nonoperative therapy is possible following such injuries [32]; however, utilization of minimally invasive therapy (i.e., ureteral stent placement or perinephric drain placement) or interventional radiology (i.e., superselective angioembolization, SSA) may be necessary to ensure successful management. In select circumstances, surgical intervention will be necessary as the initial therapy or following an attempt at nonoperative or minimally invasive approaches.

The algorithm to manage renal trauma at our level-one trauma center involves at least 24 h in the surgical ICU with serial hematocrits until the values are stable. We will also recommend bed rest until hematuria, if present, resolves. Finally, we recommend a CT with delayed images 48–72 h following acute injury to assess for new/increased urine extravasation. We recommend a repeat CT scan for multiple AAST grade III injuries and any grade IV or V renal injury. If there is an increase in urine extravasation or new extravasation, then a ureteral stent and bladder catheter is pursued. Otherwise, if there is less urine extravasation at the time of the repeat CT scan with delayed images, we will continue with no active intervention. In our series, we have noted new urine extravasation at the time of repeat imaging 48 h following a presumed renal parenchymal injury that has allowed proactive management, rather than reactive management at a later date when a urinoma might develop (Fig. 3.3). In the setting of a large perinephric

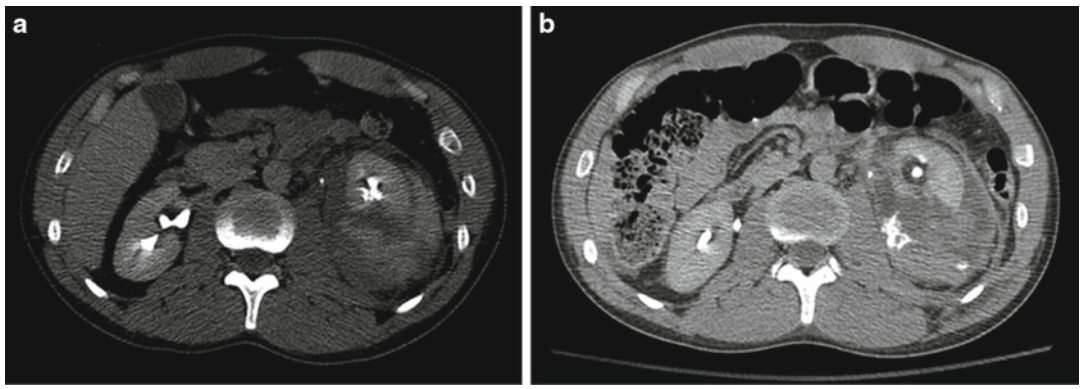

Fig. 3.3 A 45-year-old male status post-auto vs. scooter injury. Initial CT scan with delayed images at the time of admission revealed no obvious urine leak, but there was a heightened suspicion for injury (**a**). Repeat imaging 48 h later with delayed images revealed an obvious urine leak that necessitated a ureteral stent (**b**). The ureteral stent was eventually removed. Additional urological intervention was not necessary

hematoma and a single grade III renal injury, we will often recommend a repeat CT scan with an arterial phase to assess for persistent bleeding if the hematocrit has not stabilized at 48 h. Regarding patients with AAST IV and V renal injuries that do not undergo nephrectomy, a MAG3 renal scan is recommended 6–8 weeks following renal injury (or after all drains are removed) to assess final renal function. This is recommended to provide patient education and counseling regarding any diet/lifestyle changes for reduced renal function.

Surgical Management

Absolute indications for renal exploration include (1) hemodynamic instability with shock, (2) expanding/pulsatile renal hematoma, (3) suspected renal pedicle avulsion (grade V), and (4) ureteropelvic junction disruption. The intraoperative management of a nonexpanding retroperitoneal hematoma is controversial; select cases of blunt and penetrating renal trauma have been successfully managed nonoperatively [33–36]. Relative indications for renal exploration include persistent bleeding requiring >3 U RBC (threshold varies among institutions), urinary extravasation, significant devitalized renal parenchyma, and incomplete radiographic staging. Selective angioembolization may preclude the need for surgery in the setting of persistent hemorrhage; however, caution is advised that angioembolization alone may not be definitive for high-grade renal injuries [30]. A one-shot intraoperative IVU may avoid renal exploration in select cases of incomplete radiographic assessment prior to laparotomy.

Hemodynamic Instability with Shock and Pulsatile Retroperitoneal Hematoma

Preoperative CT imaging is unlikely in the setting of shock and retroperitoneal hematoma. A pulsatile or expanding retroperitoneal hematoma is commonly secondary to a renal pedicle avulsion or major renal injury, and diagnosis is often made in the operating room because the patient's clinical condition precludes preoperative CT imaging. Hematuria is not a consistent finding following these injuries; therefore, clinicians must retain a high index of suspicion despite negative tests [37, 38]. We favor renal exploration of all retroperitoneal hematomas discovered at the time of exploratory laparotomy (if no preoperative CT imaging exists), unless intraoperative radiographic studies reveal that the injury could be managed nonoperatively. Damage control may necessitate nephrectomy in the setting of hemodynamic instability with shock, with each case necessitating individualized intraoperative decision making to favor the ultimate outcome of the patient. Lastly, in the setting of persistent bleeding >3 U RBC during expectant management, renal exploration with repair or angioembolization (in hemodynamically stable patients) are therapeutic options to expedite recovery and prevent morbidity [29].

Penetrating Trauma

Historically, surgeons performed exploratory laparotomy for all penetrating abdominal trauma; however, trauma surgeons have validated and now follow nonoperative protocols after GSW and stab wounds to the abdomen [39]. Urologists have also evaluated predictors for successful expectant management of renal injuries [13, 18, 34, 40, 41]. Based upon the preceding references, the following findings predict successful nonoperative management of penetrating abdominal trauma: (1) absence of major blood loss, (2) absence of associated intra-abdominal injury, (3) absence of major renal parenchymal injury, and (4) absence of renal vascular injury.

Most penetrating injuries are associated with concomitant abdominal injury. If exploratory laparotomy is performed for concomitant injuries, renal exploration and repair should be considered for grade III or higher renal injuries. In a study evaluating nonoperative therapy after penetrating renal injuries, 23.5 % of grade III and IV renal injuries had delayed bleeding [41]. Surgical repair or angioembolization of these

injuries has been shown to be safe and effective and may eliminate potential complications [9]. Vascular injuries after penetrating renal trauma can be challenging. In one series, nephrectomy rates in the setting of renovascular injury were 32 % (8/25), with the remaining vascular injuries successfully reconstructed [34].

Stab wounds posterior to the anterior axillary line have been reported to have improved outcomes with nonoperative therapy; however, the numbers in the lone study assessing this hypothesis were small [18]. When patients with renal stab wounds were grouped by location of wound (abdomen/anterior chest, flank, and back/posterior chest), a subsequent study was unable to note any significant associations between stab injury location and outcome after nonoperative therapy [34].

High-Grade Renal Injuries (Grade IV/V)

Controversy persists in the management of high-grade renal injuries in regard to nonoperative management vs. renal exploration and repair [42, 43]. Differentiating between grade IV and V renal injuries can be challenging. If grade V injuries are defined as hemodynamically unstable, then they require immediate operative exploration. Based on this definition the management of grade IV renal injuries is more challenging, as observation, minimally invasive intervention, or open surgical intervention is possible. As with penetrating renal injuries, most grade IV renal injuries are associated with concomitant injuries that will need operative attention. Given the propensity for complications (e.g., delayed bleed, perinephric abscess), renal reconstruction should be considered in this setting. In a retrospective study evaluating isolated and nonisolated grade IV renal injuries, differences in outcomes following nonoperative and operative management were analyzed among 153 patients [42]. There was no difference in renal salvage (83 % operative vs. 88 % nonoperative); however, only 50/153 met criteria for nonoperative therapy. As would be expected, nonoperative therapy was easier in isolated renal injuries (renal explorations: 42 % isolated injury vs. 77 % nonisolated injury in the above study).

Devitalized Renal Parenchyma and Urine Extravasation

Isolated urine extravasation (except noted above) is not an indication for renal exploration as spontaneous resolution has been reported in 87–91 % of such cases [33, 44]. Medial urine extravasation or absence of ureter visualization on delayed CT imaging after major renal trauma is concerning for UPJ avulsion or renal pelvis injury and is an absolute indication for renal exploration and repair [45]. Repeat CT imaging with delayed films after 48 h is recommended in such a circumstance, with persistent extravasation on repeat imaging an absolute indication for minimally invasive management (Percutaneous nephrostomy drainage or ureteral stenting). Concomitant urethral catheter placement for 7 days (or until extravasation and hematuria resolve), and internal stenting (or nephrostomy drainage) for at least 6 weeks, is our institutional protocol for such scenarios [33]. Concomitant perinephric drain and ureteral stent placement are treatment options that should be considered in select cases, such as when a urinoma develops despite ureteral stent placement (Fig. 3.4).

The presence of devitalized renal parenchyma and active urine extravasation is a special circumstance associated with increased morbidity. In a study of 20 patients with urine extravasation after blunt trauma, 11 had coexisting devitalized parenchyma [36]. Two of these 11 injuries resolved without further intervention, and three of the nine remaining patients were managed successfully with ureteral stent and broad-spectrum antibiotics. Of the remaining six in this cohort, four needed open surgical management for infected urinoma/perinephric abscess and two sustained delayed, life-threatening hemorrhage. A similar study evaluated operative vs. nonoperative management of devitalized parenchyma and found a lower urologic morbidity rate among the surgical cohort (23 % vs. 85 %) [46]. Because of associated complications, renal explorations should be considered for grade IV renal injuries associated with >25 % devascularized renal parenchyma.

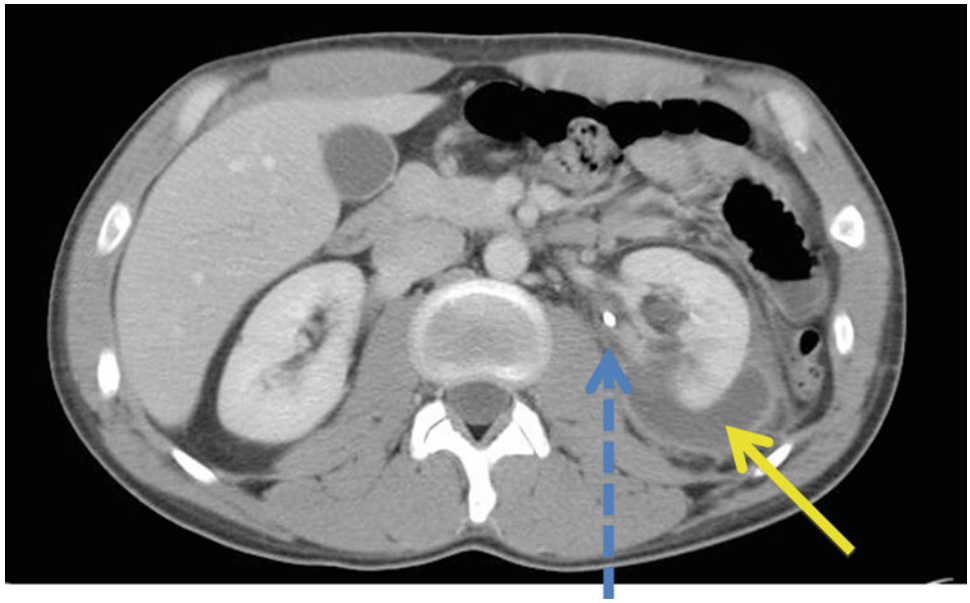

Fig. 3.4 A 23-year-old male status post-blunt abdominal injury with AAST grade IV collecting system injury. He was managed initially with a ureteral stent (*dotted line*), suppressive oral antibiotics, and urethral catheter. He presented 11 days later with symptoms consistent with a urinoma (*solid line*). A perinephric drain was placed into the urinoma by interventional radiology. Nuclear medicine study 6 weeks following removal of drain and ureteral revealed 36 % left renal function relative to the right kidney

Renovascular Injuries

Major renovascular injuries are infrequent. Among the 1.2 % of renal injuries that contribute to overall trauma, less than 4 % involve grade IV or 5 vascular injuries [47]. Renovascular injuries are best described as a laceration, avulsion, or thrombosis/occlusion, with each type of injury associated with unique outcomes.

Six level-one trauma centers combined data to assess outcomes of major renovascular injuries after blunt and penetrating trauma [47]. Eighty-nine patients were analyzed to determine predictors for poor outcome. Blunt trauma, the presence of a grade V injury, and an attempted arterial repair were negative predictors for successful recovery. Grade V renal injuries resulted in diminished renal function after revascularization likely due to associated major parenchymal damage. A recent article evaluating main and segmental renal artery injuries corroborated the dismal outcome for vascular repair of grade V renal injuries, with results similar to nephrectomy [37]. When compared to exploration, nonoperative management of segmental arterial injuries had lower transfusion requirements (4,994 vs. 820 mL) and shorter hospital stays (29 vs. 11 days) with similar mortality rates (8 % vs. 6 %). Repair of isolated renal vein lacerations resulted in few complications and good renal function, while venous avulsion and associated renal artery injury tended to fare better with nephrectomy [48].

Main renal artery thrombosis presents on CT imaging as nonvisualization of the kidney. No management algorithm exists for these injuries and retrospective studies of outcome after major revascularization demonstrate that such repairs are often unsuccessful [38]. Most injuries are secondary to blunt trauma from either deceleration injury or direct blow to the renal artery with subsequent compression against the spinal column. Few external signs and a high rate of concomitant injuries make renal artery thrombosis difficult to diagnosis in a timely manner. In a literature review by Clark and colleagues, 250 patients were diagnosed with renal artery thrombosis

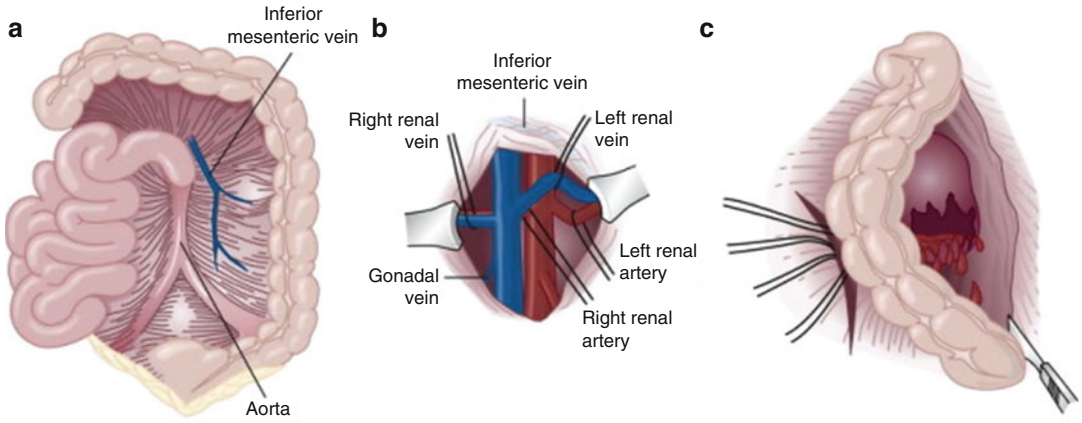

Fig. 3.5 (**a**) Midline exploratory laparotomy provides ample exposure for renal exploration. The inferior mesenteric vein is a useful landmark if retroperitoneal hematoma obscures the aorta. (**b**) Renal artery and vein relations. (**c**) Opening Gerota's fascia after obtaining renal artery/vein control (from Campbell-Walsh Urology, 10th Ed., Volume 2, Upper Urinary Tract Trauma, p. 1175, Copyright Elsevier, 2012; with permission)

from blunt trauma and revascularization was attempted in 34 unilateral injuries [49]. Success was achieved in 24 %; however, this number is likely an overestimate as follow-up was short. Surgical intervention is always recommended in bilateral renal artery occlusion and renal artery occlusion in a solitary kidney. Surgical revascularization after unilateral renal artery thrombosis may be attempted with a normal contralateral kidney, a warm ischemia time of <5 h and hemodynamic stability; otherwise, observation or nephrectomy is recommended [38]. Observation may result in delayed hypertension (HTN), necessitating long-term follow-up. HTN was found in 43 % (3/7) of observed patients in the above study, and all were successfully treated by nephrectomy. Further discussion of angiographic techniques to manage renal trauma is provided at the end of this chapter.

Operative Technique

The technique of renal exploration and repair involves the following general steps: (1) isolation of the main renal vessels, (2) complete exposure of the injured kidney, (3) watertight closure of the collecting system (if required), and (4) closure of parenchymal injuries with renal capsule, omentum, thrombin-soaked Gelfoam bolsters, or woven polyglactin mesh [22, 50].

Isolation of Main Renal Vessels

Isolation of the main renal vessels may contribute to a lower nephrectomy rate [9, 51, 52], but some clinicians do not subscribe to this view [45, 53]. The approach is easily reproducible and can be achieved in a timely manner.

A standard midline abdominal incision provides adequate exposure for renal exploration and repair. Access to the retroperitoneum is gained by lifting the transverse colon superiorly onto the upper abdomen and placing the small bowel superiorly on the chest and angled to the right. A fixed retractor system enables better visualization of the retroperitoneum during vessel identification. An incision is then made over the aorta from the inferior mesenteric artery to the ligament of Treitz (Fig. 3.5a). A retroperitoneal hematoma can prevent localization of the aorta. In this scenario, the incision will be just medial to the inferior mesenteric vein, which serves as a useful landmark (Fig. 3.5a).

The left renal vein will typically be identified first as it passes anterior to the aorta (Fig. 3.5b). After marking this vessel with a silicone vessel

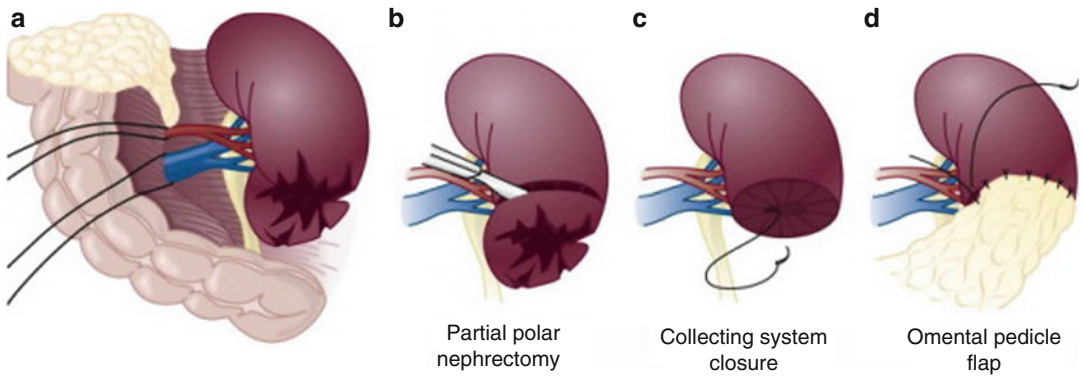

Fig. 3.6 (**a–d**). Partial nephrectomy is useful to treat upper or lower pole parenchymal injuries. An omental pedicle flap is useful to cover the defect after collecting system closure (from Campbell-Walsh Urology, 10th Ed., Volume 2, Upper Urinary Tract Trauma, p. 1176, Copyright Elsevier, 2012; with permission)

loop, the renal arteries are sought posterior to the left renal vein on either side of the aorta. A vein retractor lifts the left renal vein superiorly, thus enabling identification of the more cephalad and posterior left renal artery. The right renal artery lies between the aorta and inferior vena cava. The right renal vein is found in the region of the passing right renal artery, which crosses superiorly over it. Alternately, mobilization of the ascending colon medially allows access to the right renal artery and vein.

Vessel loops are used primarily to mark the renal vessels, with loop occlusion for significant bleeding needed in only 12 % of cases [51]. Manual compression, limiting warm ischemia time to <30 min, is first-line treatment for parenchymal bleeding. An additional option is to apply light upward traction on the renal artery vessel loop. An alternative to obtaining midline renal vascular control is to mobilize the colon medially to identify the renal artery/vein. While some have not advocated renal vascular control before opening Gerota's fascia [53], we continue to utilize this protocol.

Gerota's fascia is opened after vascular control is achieved, and the entire surface of the kidney is inspected for potential injuries (Fig. 3.5c). An attempt to preserve Gerota's fascia for hemostatic closure over the renal parenchyma after reconstruction should be attempted; however, this is not always possible if the mechanism of injury has caused collateral damage. Debridement of devitalized parenchyma is mandatory and commonly associated with GSW and blunt renal injuries. The collecting system is closed with running 4-0 polyglactin suture, while 4-0 chromic suture is utilized for parenchymal bleeding. Retrograde injection of methylene blue into the renal pelvis while compressing the ureter distally can rule out further collecting system injuries.

Upper or lower pole parenchymal injuries are best treated via partial nephrectomy with either running polyglactin closure of collecting system defects or an omental patch (Fig. 3.6a–d). An exception to this rule is a stab wound that leaves small, slit-like parenchymal defects making collecting system closure arduous. Stab wounds are associated with less tissue destruction than GSW and are often amenable to simple approximation of entry and exit wounds. Additionally, Tisseal hemostatic glue (Baxter Healthcare) may be injected into a narrow renal defect from penetrating trauma followed by watertight closure of the renal parenchyma.

Midpole renal injuries can be more complex, but initial management follows the same principle of debridement of nonviable tissue, collecting system closure, and hemostasis of bleeding parenchyma (Fig. 3.7a, b). After this is achieved, several options exist for closure of the defect, including simple closure of the renal capsule with chromic suture, closure over thrombin-soaked Gelfoam bolsters (Fig. 3.7c, d), or omental interposition.

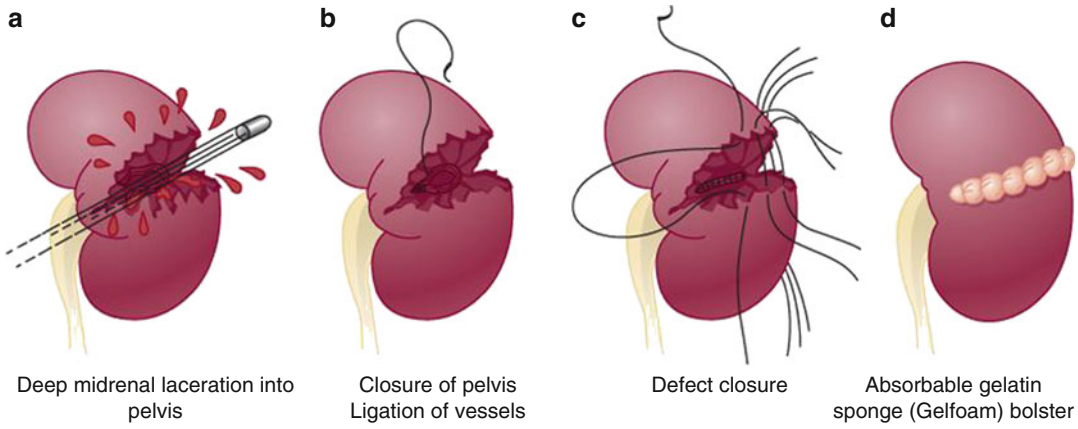

Fig. 3.7 Midpole injuries are best treated with collecting system closure and ligation of vessels. Thrombin-soaked Gelfoam can be inserted into the defect to provide additional compression while closing the outer renal capsule (From Campbell-Walsh Urology, 10th Ed., Volume 2, Upper Urinary Tract Trauma, p. 1176, Copyright Elsevier, 2012; with permission)

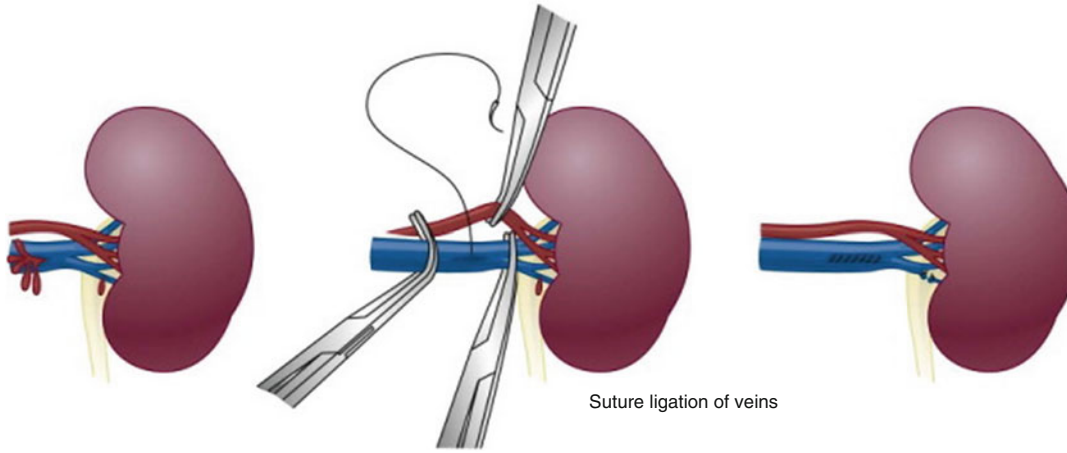

Fig. 3.8 Venous injuries to the main renal vein should be repaired while those to smaller segmental veins can be ligated

Reapproximation of Gerota's fascia provides added hemostasis to a reconstructed kidney if the original injury has left enough fascia intact. Another option is an omental pedicle flap around the repair, which provides excellent vascular and lymphatic supply to aid healing (Fig. 3.6d). Woven polyglactin mesh to cover the renal parenchyma after major reconstructions is another option when renal capsule or omentum is lacking. In this scenario, the woven mesh is tailored to the defect to be covered and buttressing polyglactin sutures are placed periodically into the renal parenchyma and overlying mesh to provide added support. Of note, associated bowel or pancreatic injury is not a contraindication for successful renal reconstruction in the setting of concomitant abdominal injuries requiring repair [54, 55].

Renal vascular injuries are associated with blood loss and possible shock. Main renal artery lacerations or avulsions commonly lead to nephrectomy; however, arterial repair should be attempted when safe. Main renal vein injuries can be closed by figure-of-eight or running 5-0 or 6-0 prolene suture while temporarily occluding the main renal artery for hemostasis (Fig. 3.8 see above). Left main renal vein injuries medial to its

branches (adrenal, gonadal, and lumbar vein) can be ligated allowing venous egress via these tributaries. Conversely, right main renal vein injuries must undergo repair or nephrectomy. Segmental arterial injuries are difficult to reconstruct; therefore, either partial nephrectomy (upper or lower pole) or debridement and re-approximation of renal parenchyma (midpole) is recommended. Since segmental arteries are end-arteries, simple ligation will result in ischemia to the respective parenchyma; however, ligation is often the only option during reconstruction. As opposed to segmental arteries, segmental vein collateral circulation allows ligation without affecting venous drainage (Fig. 3.8).

Delayed Radiographic Imaging

Postoperatively, the patient should remain on strict bed rest until (a) gross hematuria resolves and (b) serial hematocrit measurements prove stable. Computed tomography with 10 min delayed films of grade IV–V injuries within 36–72 h of injury is recommended to evaluate injury stability if nonoperative therapy was pursued [6]. Delayed imaging of grade III injuries is controversial with some evidence of missed major complications being diagnosed at the time of delayed imaging [56]. Gross hematuria that persists >7–10 days after nonoperative therapy for renal injury, in spite of bed rest, should be considered for selective angioembolization, even in the setting of stable hematocrit. Radionuclide scintigraphy (MAG 3 renogram) should be considered in grade IV–V parenchymal and renovascular injuries as a baseline evaluation 2–3 months after injury, as we have found diminished renal function on follow-up studies even in the nonoperative group [47, 57].

Complications

Secondary Hemorrhage

Delayed hemorrhage is a potentially life-threatening complication. In a series of 67 penetrating stab wounds, secondary hemorrhage presented at varied intervals after original injury (days 2–36) and was attributed to injuries at the deep cortex or medulla [6]. Approximately 20 % of nonoperative renal stab wounds will have secondary hemorrhage [41]. In this series, 23 % of nonoperative grade III–IV renal injuries had delayed bleeds vs. 0 % in the operative group. Nonoperative therapy is less common after GSW renal injuries than after stab wounds, likely resulting from a higher percentage of associated injuries needing repair and devascularization of peripheral tissues from the GSW blast effect. In fact, in a center known for its aggressive nonoperative stance in such conditions, only 38 % of abdominal GSW were nonoperatively followed [39].

Ruptured arteriovenous fistulas (AVF) and pseudoaneurysm are rare events that cause secondary hemorrhage or persistent hematuria after renal trauma. Traumatic AVFs arise after vascular injury between the vessels and have presented up to 20 years after initial insult [58].

Unlike AVFs, which may present with widened pulse pressure or hypotension, pseudoaneurysms are frequently asymptomatic until they rupture into the retroperitoneum or urinary tract causing active renovascular bleeding. Gerota's fascia typically contains bleeding after renal injury and this confined bleed may result in a pseudoaneurysm after fibrinolysis and abnormal recanalization between the intravascular space and perinephric (extravascular) tissues. The walls of such pseudoaneurysms do not contain normal muscular backing found in blood vessels, thus allowing the size to grow with fluxes in blood pressure after the injury.

The most common diagnostic and therapeutic course is angiography with ensuing superselective embolization. Most series of ruptured acquired AVF and pseudoaneurysm from trauma involve small numbers with high success rates. In one series of six patients with either AVF or pseudoaneurysm, all were successfully treated in one session with no complications [59]. The largest series we discovered in the literature was of 42 patients who underwent embolization for pseudoaneurysm and AVF after major renal trauma [60]. Successful resolution was achieved in 35/42 (87.5 %).

Perinephric Abscess/Urinoma

Symptoms secondary to urinoma are often absent, but they can present as nonspecific abdominal tenderness, low-grade fever, or ileus. An elevated white blood cell count or blood urea nitrogen level may be present. Delayed images on CT are ideal for radiographic diagnosis. As discussed above, most urinomas will resolve spontaneously; however, for those that do not, internal ureteral stent and urethral catheter drainage with or without additional percutaneous drain placement is recommended. Urinoma associated with devitalized renal parenchyma requires more aggressive management given the higher complication rate (see above). Regarding perinephric abscess or infected urinomas, percutaneous drain placement has generally replaced open surgical drainage, with open intervention reserved for percutaneous failures or selected initial presentations [6].

Hypertension

HTN resulting from renal trauma has always been regarded as a treatable complication that deserves surveillance. The etiology is thought to be secondary to subcapsular hematoma leading to chronic renal compression (Page kidney) [61]. Ensuing renal ischemia leads to elevated renin secretion in an effort to increase systemic blood pressure. Main renal artery compression or ischemia (i.e., renal artery thrombosis) can also lead to elevated renin secretion (Goldblatt kidney) [62]. Both models are easily corrected with nephrectomy, revascularization, or medical therapy. Periodic blood pressure screening is recommended to enable diagnosis and treatment. In a major retrospective review of renovascular injures from six trauma centers over a 16-year period, post-trauma renal HTN was detected in 4/87 patients [47]. In a different study spanning 20 years, HTN was diagnosed between 2 weeks and 8 months after initial injury in seven patients sustaining renal injury [63]. Lastly, blunt renal trauma causing post-trauma HTN was diagnosed in 10 of 17,410 HTN referrals to a general medical clinic [64].

Renal Insufficiency

Most would agree that major renal injuries deserve attempted reconstruction to maximize future renal function. However, others would argue that this pursuit could compromise renal function or lead to unneeded nephrectomy. The ideal population to evaluate is those with high-grade renal injuries. In the setting of grade IV–V renovascular injuries that were treated by operative ($n=68$) and nonoperative ($n=21$) means, diminished renal function (<25 % renal function on follow-up nuclear scan) and renal failure (serum Cr > 2 ng/mL and dialysis) were present in 14/89 and 6/89, respectively [47]. The true impact on renal function will never be known, since follow-up studies for renal function were not achieved in all patients.

In the absence of trials to assess these arguments, physicians will never know the ideal path to follow. One of the most recent reports on this topic sought to compare outcomes on renal function between a similarly matched cohort of nephrectomy and renorrhaphy patients [65]. The authors argued that nephrectomy should always be avoided if possible; however, their conclusion was that reconstruction does not offer any clinical benefit for postoperative renal function. Their results and conclusions were only applicable in the immediate postoperative period. Duration of follow-up was not provided and "long-term data on renal function were unavailable" [65]. Such a statement is oversimplified. Renal reconstruction should not be thought of as only aiding recovery in the acute setting; rather, consideration for the future should always be regarded as important. If such an approach is taken, it is difficult to apply the above-mentioned studies to clinical practice.

Other Considerations

Superselective Angioembolization

SSA is emerging as an alternative to surgical management of blunt and penetrating renal trauma. With the advent of small coaxial catheters, interventional radiologists are able to access

segmental branches, as opposed to earlier decades when embolization was only possible in larger, more proximal vessels leading to considerable loss of renal parenchyma. Most series involve small numbers of patients with variable presentations of delayed vs. acute bleeds making interpretation of specific indications difficult [28, 59, 60, 66–68]. Long-term complications (>30 days) after SSA include delayed HTN, abscess, and impaired renal function, while short-term complications (<30 days) consist of back pain, increased white blood cell count, fever, or emesis (traditionally called post-embolization syndrome) [28]. Other acute complications include renal artery dissection, which is reported to occur during SSA in approximately 7.5 % of patients [60].

Almost all reporting institutions avoid SSA in cases of pedicle avulsion and hemodynamic instability. However, one group has utilized SSA for parenchymal grade V injuries in 2/9 patients with successful resolution of bleeding; however, the impact on residual renal function was not provided. A separate series of SSA for renal hemorrhage included 18 patients, with 9/18 secondary to trauma [29]. Embolization proved successful for all grade IV injuries; however, no grade V injury ($n=5$) was amenable to embolization alone. Finally, an analysis using the National Trauma Data Bank assessed national trends for angiography and angioembolization following renal trauma [30]. Seventy eight percent of the cohort sustained AAST 3–5 renal trauma. Notably, 68/77 patients who underwent initial selective angioembolization required successive intervention, with repeat angioembolization the most common procedure. Despite the need for repeat procedures, the renal salvage rate was 92 %.

Post-embolization syndrome is the most common early side effect reported after SSA and universally is self-limited. In regard to long-term complications, delayed HTN was not reported among any of the above-mentioned studies. One series did include two patients who underwent delayed, elective open exploration for persistent flank pain/hematoma in one and clinical suspicion of infected hematoma in the other [66]. Both were converted to nephrectomy after attempt at partial nephrectomy was unsuccessful.

Endovascular Stents

Endovascular stent for the management of renal artery dissection is a rare reported treatment [68–71]. As the mechanism behind such injuries is rapid deceleration, all were after blunt renal injury. The sum total of patients in the four studies was five. Four of these patients were successfully treated by endovascular stent alone, with the sole remainder successfully managed with urokinase and endovascular stent. One patient with a solitary kidney required temporary hemodialysis, with normal return of renal function 37 days after the injury [70]. Duration of time between injury and stent placement was reported in two of the three studies (2.5 and 9 h after injury) [70, 71]. Both studies documented normal renal function (Cr 1.1 ng/mL in both) at 4 months and 4 years after incident. Despite the limited number of series, there is limited experience with endovascular stents in the setting of renal artery dissection. Utilization of endovascular stents should be used with caution, as the potential need of anticoagulation (for the stent) in the setting of trauma often precludes use.

Conclusions

Management of renal trauma has evolved over the past decade to include a higher percentage of nonoperative therapy. Surgeons must be knowledgeable of the appropriate clinical and radiographic signs for appropriate application of this strategy. Most grade V renal injuries will require nephrectomy, while successful renal salvage of grade III–IV renal injuries can be challenging. An understanding of the indications for surgical intervention for grade III–IV injuries is vital to maximize favorable patient outcome and reduce morbidity. Nonoperative management of AAST grade I and II renal injuries should be pursued to prevent unnecessary nephrectomy procedures. The surgeon must be committed to the

practice of renal reconstruction because unnecessarily high nephrectomy rates have occurred in the setting of an inexperienced or uninformed surgeon (i.e., lack of preoperative imaging). Lastly, certain scenarios can arise during or after management of renal trauma, jeopardizing eventual patient outcome. As such, scheduled radiographic imaging after operative and nonoperative management of specific renal injuries should be considered.

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Traumatic Ureteral Injuries

4

Joshua A. Broghammer and James M. Hotaling

Introduction

Injuries to the ureter are rare but can pose a significant clinical challenge. Although the majority of injuries in civilian hospitals occur as intraoperative complications, this chapter focuses on the presentation, diagnosis, and surgical management of ureteral injuries from external trauma. Despite their relative rarity, traumatic ureteral injuries are often difficult to manage due to the acuity of patient illness secondary to other associated injuries, frequent delay in diagnosis, and the need for a broad armamentarium of surgical reconstructive techniques.

Epidemiology

More than 2.8 million people in the United States are hospitalized every year due to injury [1]. Trauma is the leading cause of death in those under the age of 45 [2]. Genitourinary injury rates are relatively low and account for approximately 10 % of traumatic injuries [3]. The vast majority of ureteral injuries today are derived from iatrogenic surgical injuries [4]; 2 % of all hysterectomies and 5 % of all ureteroscopies result in ureteral injury [5, 6]. Ureteral injuries due to trauma are far less common, comprising less than 1 % of all genitourinary injuries [7–9]. Due to the relative rarity of traumatic ureteral injuries, a busy urban trauma center can expect to see 5–8 injured ureters per year [7, 10–12]. Thus, much of the literature on the presentation, diagnosis, and management of ureteral injuries has been derived from retrospective single institution case series.

Etiology

Descriptions of ureteral injuries are broken down by mechanism: blunt or penetrating. Penetrating mechanisms are further subdivided into gunshot wounds (GSW) or stab wounds. Penetrating mechanisms encompass 90 % of traumatic ureteral injuries [4]. Stab wounds account for 9 % of injuries, whereas GSW account for 81 %. Overall, 3 % of all GSW will result in a ureteral injury [13, 14]. The remaining 10 % of injuries stem from blunt mechanisms. A recent analysis of the National Trauma Data Bank by Siram et al. shows the percentage of blunt injuries may actually be higher at 38.5 % while penetrating accounts for 61.5 % of injuries [9]. It is unclear why the percentage of blunt ureteral injuries is increased in this analysis. A number of possibilities include selection bias by participating institutions,

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inaccurate coding of injury mechanism, or inaccurate coding of injury type, such as misclassification of grade IV renal lacerations with urinary contrast extravasation. Elliott and associates concluded that this trend may be due to multiple series reporting only penetrating injuries, thus historically biasing analysis of the literature toward an overrepresentation of penetrating injuries [7]. Mechanism is important to consider because the management of these injuries is often dictated by their etiology.

Penetrating Injury

GSW account for 54–81 % of ureteral injuries [7, 9, 14]. When evaluating a firearm related wound with potential ureteral involvement, it is vital to take into account the hemodynamic stability of the patient and their associated injuries. Fatality rates in those with ureteral injury range from 6 to 17 %, although historical series may be higher [9, 10]. It is difficult to determine the contribution of the ureteral injury to mortality, but in general it is attributed to associated injuries which will occur in more than 90 % of patients suffering GSW [9, 10, 12, 14, 15]. Small bowel and large bowel injuries occur in 46–62 % and 44–51 %, respectively [11, 16]. Vascular injuries are seen in 13–38 % of patients [9, 11, 16].

Stab wounds account for 5–9 % of all ureteral injuries and typically result in damage to a short ureteral segment [9, 14]. Although associated organ injury can still be present, unlike GSW there tends to be less surrounding tissue destruction due to the nature of the injury. Stab wounds posterior to the mid-axillary line or abdominal wounds with long blades are exceedingly likely to result in a ureteral injury [4, 7, 8, 12]. Long blade injuries can be confounded by the fact that the entrance wound may be on the side opposite to the location of ureteral injury.

Historically, the literature is replete with discussions regarding bullet wounding characteristics and high-velocity vs. low-velocity projectiles. The path of a bullet creates two forms of damage, the first being direct penetrating injury along its trajectory. Additional damage occurs as kinetic injury is transferred into the soft tissues resulting in a cavitary defect and subsequent microvascular damage to surrounding structures. In an experimental study of high- and low-velocity wounds, Amato et al. demonstrated that microvascular damage can be seen 2 cm from the course of the missile [17]. Even, low-velocity GSW can cause damage to a ureter that is not detectable on initial imaging studies or intraoperative exploration and may present as a urinoma several days later due to subsequent tissue necrosis and ureteral breakdown [18].

More recent studies have suggested that the surrounding tissue injury from high-velocity rounds may be overestimated, especially in military, fully jacketed rifle rounds. These rounds are designed for increased range and penetration, which makes them more likely to pass through a target rather fragmenting and transferring their kinetic energy. This results in less tissue damage than seen with unjacketed, hunting rounds [19]. In a recent review on ballistics and wounding, Santucci and associates concluded that judicious debridement of wounds should be used to limit the possibility of iatrogenic injury and not based on the velocity of the missile alone [20].

Blunt Injuries

Blunt ureteral injuries are relatively rare and typically occur in the pediatric population where the flexibility of the spine predisposes them to mid ureteral or ureteropelvic junction disruption in high-velocity mechanisms such as falls from heights or high speed motor vehicle collisions [21, 22]. The mechanism of injury is due to rapid deceleration or hyperextension injuries resulting in traction along fixed portions of the ureter, typically at the ureteropelvic or iliac artery. Although thought to be rare in adults, cases have been reported and may be underrepresented in the literature [9, 14, 23]. Looking at the National Trauma Data Bank and more historical series, 10–38.5 % of patients experienced ureteral injuries secondary to blunt trauma [9]. These patients tend to

present with multiple acute injuries secondary to polytrauma [13]. When compared to patients with penetrating ureteral trauma, those with blunt ureteral injury had a higher injury severity score of 21.5 vs. 16.0 and a higher propensity toward bony fractures of the vertebrae and pelvis, indicating impacts with high amounts of kinetic energy [9].

Anatomy

Anatomically, the ureter is a 22–30 cm long thick-walled narrow tube varying in diameter from 1 to 10 mm [10]. It has three distinct layers: an outer adventitial sheath which contains the ureteral blood supply, a medial layer with longitudinal and circular smooth muscle fibers, and a lining made of transitional epithelium. The ureteral artery provides the blood supply to the ureter and consists of an anastomotic network wrapping around the ureter in the adventitial layer. Despite this, the ureteral artery lacks significant collateral flow in 80 % of patients [24, 25].

Ureteral injuries due to trauma are rare due to the protection of the ureter in the retroperitoneum by the thickness of the psoas muscle and bony surrounding structures such as the pelvis and vertebrae [13, 25]. The proximal right ureter lies posterior to the duodenum and is lateral to the inferior vena cava. The ileocolic and right colic cross the right ureter anteriorly. The left proximal ureter is posterior to the ligament of Treitz and the pancreas. It is bordered anteriorly by the inferior mesenteric artery and sigmoidal vessels which cross below the left ureteropelvic junction. Significant collateral damage is often seen in ureteral injuries due to proximity of the ureter to other surrounding structures [13, 26, 27].

The ureter is divided into three segments (Fig. 4.1) [10]. The proximal ureter is the portion from the ureteropelvic junction to where the ureter crosses the sacroiliac joint, the mid ureter extends from the sacroiliac joint through the bony pelvis to the iliac vessels, and the distal ureter extends from the iliac vessels to the bladder. The proximal ureter receives its blood supply medially from the renal arteries and the aorta and the distal portion receives its blood supply laterally from branches of the internal iliac artery including the uterine and superior vesical arteries. The mid portion relies on arterioles which travel longitudinally from above and below [25]. Mobilization of the ureter must proceed according to the anatomic location of the blood supply. Further, the surgeon must remain aware of possible ureteral anomalies which can alter its course (retrocaval, ectopic, cross-fused renal ectopia) or number (duplication). Understanding the blood supply of the ureter is critical to prevent iatrogenic injury and ischemia during surgical repair of traumatically injured ureters.

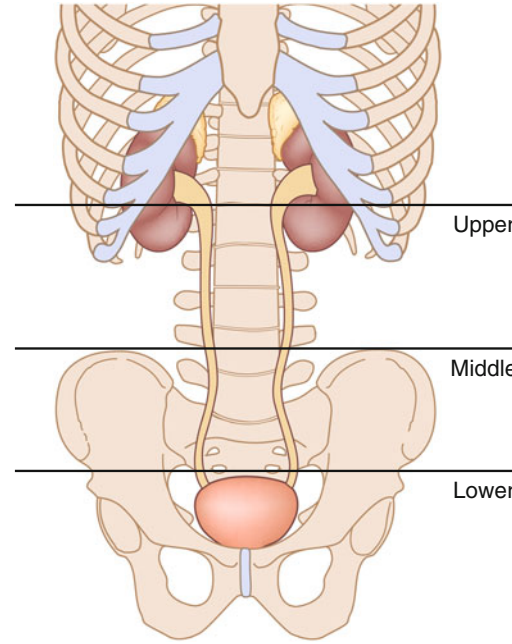

Fig. 4.1 Anatomic divisions of the ureter (courtesy of BioMed Central [10])

Knowledge of the course of the female pelvic ureter is essential for recognizing and repairing both iatrogenic and traumatic ureteral injuries. Briefly, the pelvic portion of the ureter lies posterior to the infundibular pelvic ligament, passes anteromedial to the base of the broad ligament, and lateral to the uterosacral ligament where it is crossed in an anterosuperior fashion by the uterine artery [25].

Presentation

Ureteral injuries can be difficult to diagnose in the severely injured trauma patient. The majority of patients with ureteral injuries are extremely ill, with roughly 90 % having associated injuries, including small or large bowel injuries [10]. Nearly 17 % will present with hypotension regardless of the mechanism of injury, and hypotension has been as high as 56 % in some series [7, 9]. In those with penetrating injuries, appropriate surgical assessment must be undertaken. In appropriately selected penetrating mechanisms or those with blunt abdominal trauma from rapid deceleration injuries, the patient should proceed to appropriate radiological testing.

Table 4.1 Demographics and outcomes of 1,021 patients with ureteral injury

Variable	% (±SD) or mean (±SD)
Age (years)	23.2 (12.1)
% Male	83.4 (28.5)
% Proximal UI	59.7 (37)
% Middle UI	25.6 (30.4)
% Distal UI	20.8 (24.4)
% Associated injuries	90.4 (26.2)
% Hematuria on admission UA	44.4 (36.3)
% UI detected on IVP	57.2 (38)
% UI detected on CT and/or RPG	88.3 (28.2)
% UI with complications	36.2 (34)
% UI missed	38.2 (39.5)
Associated mortality	17

Adapted from Pereira et al. [10]
UI ureteral injury, *CT* computed tomography, *IVP* intravenous pyelography, *RPG* retrograde pyelography

Hematuria

Hematuria remains a poor indicator of ureteral injury. Pereira et al. recently analyzed traumatic ureteral injuries in a meta-analysis, which is the largest summary of the literature to date [10]. An Embase, Cochrane, and Pubmed search yielded 77 retrospective reviews with a total of 1,021 patients. The results of this meta-analysis are outlined in Table 4.1. This analysis demonstrated that only 44 % of patients with a proven ureteral injury had hematuria on their admission urinalysis [10], consistent with many previous studies that have also found hematuria to be a poor marker of ureteral injury. Gross hematuria is present in only 46 % of ureteral injuries and microhematuria is present in only 36 % cases of ureteral trauma. Instead, these studies emphasize an investigation of ureteral trauma based on the mechanism of injury [11, 13, 14, 28, 29]. The absence of blood on urinalysis is thought to come from a complete transection or an adynamic, partially injured segment. This type of damage to the ureter prevents the passage of urine through the site of injury and reduces the chance of hematuria. Additionally, ureteral traction injuries or GSW, in which the ureter may be injured by the blast effect, can become ischemic but are unlikely to cause hematuria [11]. The absence of hematuria should not be used clinically to rule out a ureteral injury [30].

Radiologic Imaging

The timing of radiologic imaging can be difficult in the patient with ureteral injury due to the presence of potential life-threatening associated injuries. The ideal form of imaging would be one which can be performed quickly, provides the most anatomic detail of injury location, minimizes radiation exposure to the patient, and has both a high specificity and sensitivity. The optimal imaging study in a stable patient is a contrast-enhanced computerized tomography (CT) with delayed views of 10–15 min (CT-IVP). This has become the gold standard in the assessment of abdominal trauma [31, 32]. Similar to intravenous pyelogram, signs of ureteral injury on CT-IVP include: contrast extravasation, hydronephrosis, and lack of distal ureteral filling. Another hallmark sign seen on CT is the extravasation of perirenal contrast which indicates injury to the ureteropelvic junction (Fig. 4.2) [32–34]. Unfortunately, CT-IVP is

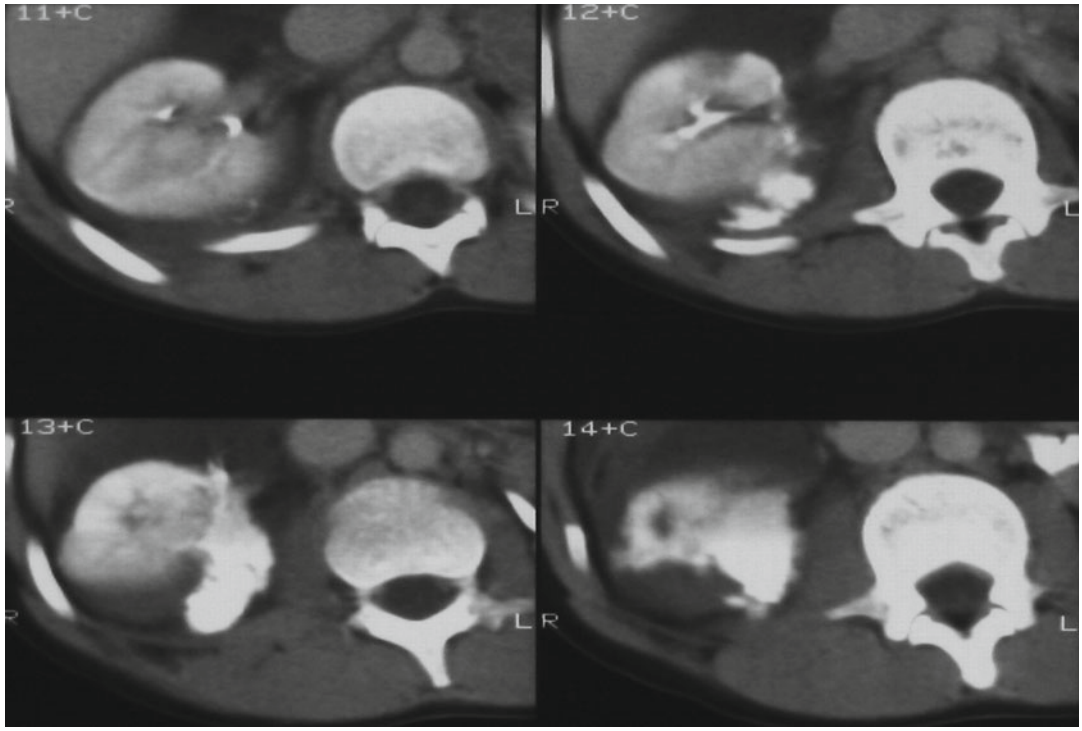

Fig. 4.2 Computed tomography demonstrating right-sided medial contrast extravasation indicative of a renal pelvis laceration (adapted from Wein et al. [3]; with permission)

plagued by some of the same issues as other imaging modalities, mainly that it is time-consuming and may not be appropriate for acutely ill patients.

The most sensitive radiologic study for assessing the ureter is a retrograde pyelogram, but this is impractical due to the acuity of patients in a trauma setting. Studies such as intravenous urogram (pyelography) can delay care as they require assessment in the radiology suite. In addition, the administration of contrast in a hypotensive patient may not show timely excretion into the collecting system, thereby further delaying diagnosis. It is essential that the patient be resuscitated prior to contrast administration. Pereira et al. demonstrated that intravenous urography was able to diagnose a ureteral injury in only 57 % of cases (Table 4.1) [10]. A similar result was found in an analysis by Elliot and associates, in which intravenous urography was only accurate in 61 % of cases [14]. The key hallmark of ureteral injury is extravasation of contrast, but ureteral injury must be suspected in those with failure to visualize the distal ureter, or the presence of hydronephrosis.

The acutely unstable patients with failed attempts at resuscitation and those with penetrating abdominal injuries are often taken immediately to the operating room for exploration of the abdomen. This prevents a proper radiological survey of damage to the urological system. A one-shot (intraoperative) intravenous pyelogram may be performed to assess renal function, presence of a contralateral kidney, and urinary extravasation of contrast [35]. A bolus of 2 mL/kg of intravenous contrast material is given and a single abdominal film is taken 10–15 min after contrast administration. This is not without controversy, however, as many authors have advocated it is not accurate enough for practical use [10, 11, 30]. Conclusions are difficult to make as the literature is confounded by the fact that the type of intravenous urography performed (formal intravenous pyelogram vs. one-shot intravenous pyelogram) is often not detailed [14].

Direct Ureteral Inspection

Previous work has shown that the most sensitive test for ureteral injury is intraoperative exploration of the ureter by a urologist [7, 10, 14, 16, 30, 36]. The overall range of success is variable, depending on the case series, but Pereira's meta-analysis has shown an intraoperative rate of ureteral injury detection at 62 % (±38.8) (Table 4.1) [10]. Some series are as high as 100 % [36]. The retroperitoneum should be opened via mobilization of the colon, and the course of the ureter should be traced via direct visualization. Any retroperitoneal hematoma in the region of the ureter should be thoroughly examined. In penetrating wounds one should determine the trajectory of the injury to help aid in localization. Any sign of contusion, lack of bleeding, or discoloration can signify injury. Intravenous injection of methylene blue or indigo carmine dye can be used to determine the location of injury. Hypotensive patients may not have adequate renal perfusion and direct intraureteral injection of methylene blue will help facilitate diagnosis. If the patient has suffered an accompanying bladder injury, the authors have found the placement of bilateral, intraureteral 5 French pediatric feeding tubes or Pollack catheters useful for quick ureteral localization. It is imperative that ureteral injuries be diagnosed as delays have been shown to increase complication rates [27].

Delayed Diagnosis

Delayed diagnosis remains a significant problem for patients with ureteral injuries. When the injury is not immediately recognized, patients may present with an infected urinoma or uremia days to weeks later [27, 29]. Other signs of delayed presentation can include prolonged ileus, infection or sepsis, fistula formation, obstruction with or without flank pain, renal failure, and persistent urinary leakage via incisions. Patients presenting with delayed ureteral injuries should be initially managed with cystoscopy and attempted retrograde stent placement [37, 38]. Failure of stent placement necessitates urinary drainage via percutaneous nephrostomy tube with later conversion to an antegrade stent in the case of partial injuries. In cases when an antegrade stent cannot be passed through the injury site, a nephrostomy tube is left in place and ureteral reconstruction is performed at a later date [39]. Residual urinoma can be drained percutaneously if needed.

Table 4.2 AAST organ injury scale for ureteral injuries[a]

AAST	Ureteral injury grade
I	Contusion or hematoma without devascularization
II	<50 % transection
III	>50 % transection
IV	Complete transection with <2 cm devascularization
V	Avulsion with >2 cm devascularization

[a]Data from Moore et al. [40]

Surgical Management

Injury Staging

The American Association for the Surgery of Trauma (AAST) organ injury scale is used internationally to grade the severity of ureteral injuries (Table 4.2) [40].

This scale is useful for research purposes and for quantifying the degree of injury to the ureter. Practically, any grade II injury or higher should be considered for open repair and all grade IV and V injuries should be treated with open surgery. The severity of the AAST injury grade has also been shown to correlate well with the severity and number of other associated injuries [13]. This is clearly demonstrated in the table from a paper by Best et al. [13] (Table 4.3).

Timing of Ureteral Repair

Ureteral injuries have a high degree of associated injuries [7, 9, 10]. Although associated injuries are not in and of themselves a contraindication to surgical repair of the ureter, the hemodynamic stability of the patient must be taken into account.

Table 4.3 Associated injuries vs. AAST grade for ureteral injuries[a]

Organ	No. grade I (%)	No. grade II (%)	No. grade III (%)	No. grade IV (%)	No. grade V (%)	Total no. (%)
Overall	5	20	32	33	32	122
Small bowel	2 (40)	6 (30)	12 (37.5)	13 (39.3)	7 (21.8)	44 (36)
Colon	1 (5)	4 (20)	3 (9.5)	4 (20)	4 (20)	13 (13)
Iliac vessels						
Artery		1 (5)	3 (9.5)			4 (3.2)
Vein			4 (12.5)			4 (3.2)
Stomach			2 (6.2)	2 (6)	2 (6)	6 (4.9)
Kidney	1 (20)			2 (6)	2 (6)	5 (4.1)
Liver	1 (20)		2 (6.2)	2 (6)		5 (4.1)
Pancreas		1 (5)		2 (6)	2 (6)	5 (4.1)
Bladder			1 (3.1)	3 (9.3)		4 (3.3)
Duodenum		2 (10)	1 (3.1)			3 (2.4)
Bone		1 (5)	1 (3.1)	1 (3.1)		3 (2.4)
Head			2 (6.2)			2 (1.6)
Thorax			1 (3.1)		1 (3.1)	2 (1.6)
Diaphragm		1 (5)				1 (0.8)
Gallbladder			1 (3.1)			1 (0.8)
Gonadal vessels					1 (3.1)	1 (0.8)

[a]From Best et al. [13]; with permission

Many complex ureteral repairs are time-consuming and would not be appropriate in the acute setting. Patients with acidosis, hypothermia, hemodynamic instability, fecal contamination, or coagulopathy should be managed with a staged repair or in a "damage control" fashion [41]. Gross fecal contamination can complicate ureteral repair. Immediate repair should be deferred until bowel repair or diversion is performed and multiple abdominal wash out procedures have been completed to reduce infection. The ureter is temporized by ligation at the area of injury with a large nonabsorbable suture for easier identification upon re-exploration. A large drain is placed in the retroperitoneum to drain any potential urine which may collect. The patient can then be brought to the intensive care unit for further resuscitation. The ligated ureter is managed with a percutaneous nephrostomy performed in an interventional radiology suite when hemodynamic stability has been achieved. Open nephrostomy tube placement should not be considered as it is often both difficult and time-consuming. The ureter should be marked with a radio-opaque surgical clip so that the location of the distal ureter can be better identified on any future radiographic studies used for surgical planning. If there are plans to return to the operative suite within a few days after injury and following proper resuscitation, more short-term temporizing measures can be performed. An end ureterostomy is performed by bringing the ureter through an abdominal stab incision and sewn to the skin or drained via a feeding tube or central line.

Ureteral repair should be considered when the patient has recovered from their associated injuries. Any inflammatory process in the pelvis, ureter, and retroperitoneum, including fecal contamination, should have adequate time to resolve. Proper surgical planning should include renal nuclear scintigraphy if there is a concern for renal function based on associated kidney injury or prolonged renal obstruction due to a missed ureteric injury. Retrograde and antegrade ureteral studies should be used to determine ureteral length and injury location. Bladder capacity should be tested either radiographically or through a filling cystometrogram to determine the feasibility of bladder use in the reconstruction.

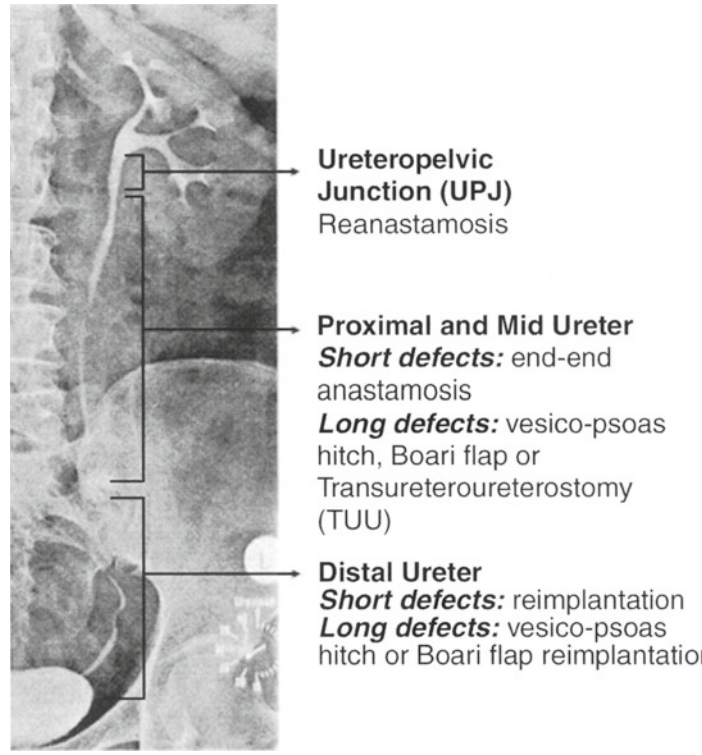

Fig. 4.3 Type of ureteral repair based on injury location

Injury Location

The level of ureteral injury dictates the type of repair required. Factors to be considered include both the length of ureter available and location of intact ureteral blood supply. Contemporary series show great variability in injury location. The meta-analysis by Pereira et al. revealed that the majority of patients, 59.7 % (±37), had proximal injuries, while mid ureteral and distal ureteral injuries occurred at 25.6 % (±30.4) and 20.8 % (±24.4) respectively (Table 4.1) [10]. Other large series have similar rates of injuries based on location: upper 15–39 %, mid 31–37 %, lower 30–37 [7, 12, 13]. The types of repairs based on location of ureteral injury are summarized in Fig. 4.3.

Operative Techniques

Principles of Surgical Repair

Repair of ureteral injuries is grounded in a number of key principles regardless of which type of reconstructive operation is selected [3]. The injured portion of the ureter must be judiciously debrided of nonviable tissue and cut back to bleeding ureteral edges. The ureter is mobilized with minimal handling and care not to disrupt the surrounding blood supply. One must avoid ureteral skeletonization to prevent injury of adventitial vessels and subsequent ureteral devascularization. The ureter is spatulated to create a tension-free, water tight, anastomosis with a 4-0 or 5-0 self-absorbable suture. The anastomosis should be stented and the retroperitoneum drained. Passive drainage can be chosen if near the ureteral anastomosis. Sump drains should be placed more distantly to prevent urine from being suctioned through the anastomosis, creating a fistula. If possible, the repair should be isolated with an omental interposition flap, especially if there is an associated vascular or intestinal injury.

Endoscopic Management

Endoscopic management has a limited role in the management of ureteral trauma. Retrograde pyelogram has the highest sensitivity in the detection of ureteral injuries, but the role is

limited in the acute setting. However, it is appropriate in those presenting in a delayed fashion. Minor ureteral contusions (grade I) can be managed with internal ureteral stents [30]. Care must be taken as small contusions may necrose resulting in breakdown or form stricture secondarily to microvascular damage at the time of injury [3]. Close monitoring of the ureter is required through both the acute and posttreatment setting. Cases in which the extent of the contusion is unclear are better treated with excision and ureteroureterostomy.

Primary Repair

Primary repair of the ureter is performed by closure of an injury over a stent with 4-0 or 5-0 self-absorbable suture. This technique is used in a limited capacity and is best reserved for partial transection (grade II) injuries from penetrating stab wounds when there is no need for mobilization, spatulation, or debridement. This typically leaves a short injury with clean ureteral edges which are easily repaired. A consideration for primary repair of larger, partial transection (grade III) injuries can be made in unique situations with minimally damaged ureteral edges and little surrounding tissue injury, but it is generally not recommended. Examples of such injuries should be limited to stab wounds. Blunt avulsion injuries and GSW should not be repaired in this fashion due the risk of delayed necrosis of the ureter from microvascular thrombosis and surrounding soft tissue injury.

Ureteroureterostomy

The vast majority of ureteral repairs in the upper and mid ureter above the pelvic brim are done with a simple ureteroureterostomy [14]. This technique is ideally suited for short segment injuries (grade II–IV) in the mid and proximal ureters. The ends of both the proximal and distal ureteral segment are debrided to bleeding edges. Opposite spatulation of both ends and closure over a stent with fine, self-absorbable suture is performed. Minimal tissue handling techniques including use of stay sutures and optic magnification help prevent ureteral devascularization and subsequent stricture. If associated abdominal injuries are of concern, an omental flap can be used for coverage of the repair.

Ureteroneocystostomy (Ureteral Reimplant)

Ureteroneocystostomy or ureteral reimplant is ideally suited for distal ureteral injuries. Ureteral mobilization, debridement, and spatulation of the ureter are performed. The most common reimplantation technique is a non-tunneled ureteral anastomosis (Fig. 4.4). The bladder is opened anteriorly and a small cystotomy is made in the superior-lateral portion. The ureter is brought through the cystotomy and the ureteral opening is secured to the surrounding mucosa with fine self-absorbable suture and stented. The bladder is closed in two layers with self-absorbable suture and a Foley catheter placed for drainage. The Foley catheter is removed in 7–10 days, after confirmation of bladder healing with cystogram. This non-tunneled method has an advantage of being done more quickly and may be better suited for unstable patients that need to be rapidly repaired. A history of urinary tract infections is a relative contraindication due to theoretical increased risks of pyelonephritis due to a refluxing anastomosis. However, several series have shown that a refluxing anastomosis doesn't carry an increased risk for renal loss, recurrent infection, anastomotic urine leak, or ureteral stricture when compared to a non-refluxing anastomosis [42, 43].

An alternative form of ureteroneocystostomy is the Politano-Leadbetter technique. A cystotomy is made and the ureter is tunneled under the submucosa, both medial and superior to the native orifice [44]. A non-refluxing anastomosis is created with a 3:1 ratio of tunnel length to ureteral diameter. Other forms of ureteroneocystostomy have been described including extraperitoneal reimplantation such as the Lich-Gregoir technique [45, 46]. Comparisons of the Politano-Leadbetter and Lich-Gregoir technique have revealed similar results of complications rates in the transplantation literature and may be an acceptable alternative depending

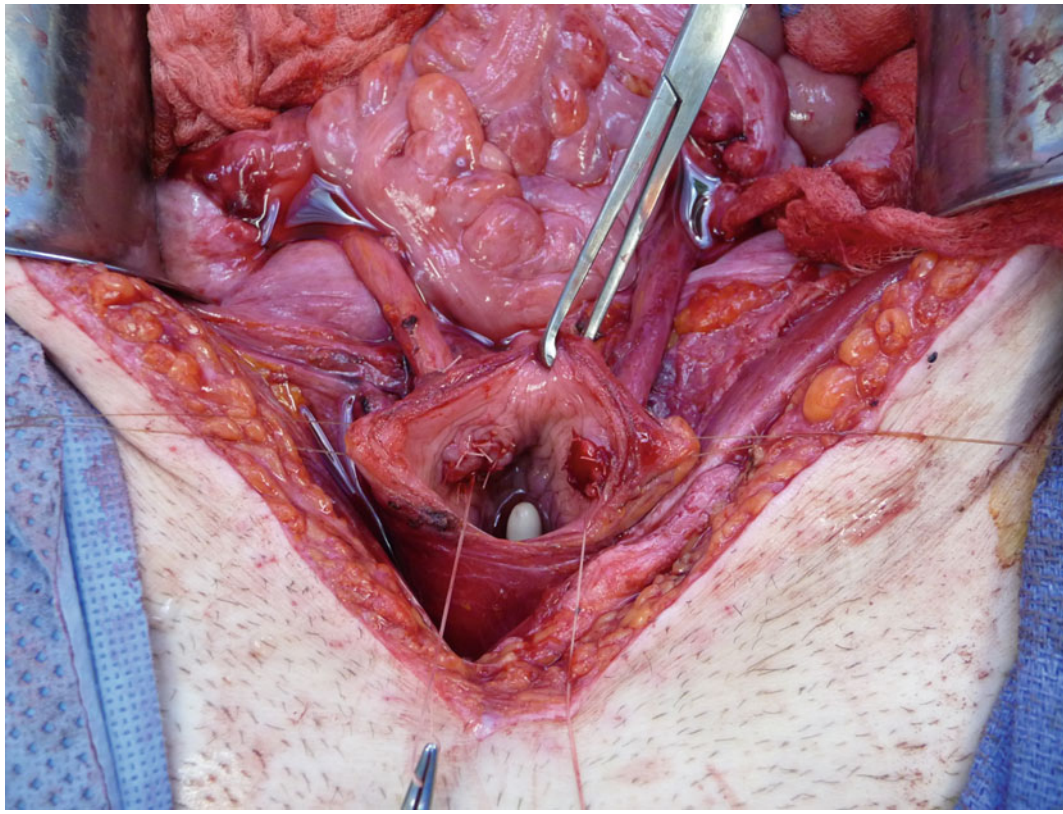

Fig. 4.4 Right and left refluxing ureteroneocystostomies in a patient with bilateral, distal ureteral injuries

on surgeon comfort [47, 48]. Recently, laparoscopic ureteroneocystostomy has shown good success in staged repairs [49]. The increased complexity of laparoscopy is not warranted in the setting of an acute repair.

Vesico-Psoas Hitch

Distal ureteral injuries which are too long to be bridged by ureteroneocystostomy alone are best managed with a vesico-psoas hitch (Fig. 4.5) [50]. The peritoneal reflection is mobilized off the surrounding bladder. If additional bladder length is required, the contralateral superior vesical artery can be ligated for better mobilization. A transverse incision is made in the anterior bladder wall perpendicular to the injured ureter and two fingers are inserted into the bladder dome to direct the bladder over the ipsilateral psoas tendon. Monofilament, nonabsorbable sutures are placed through the bladder serosa and secured to the psoas tendon. Care is taken to avoid genitofemoral nerve impingement. The ureter is reimplanted medial to the hitch as described above and the bladder is closed in two layers, perpendicular to the cystotomy in a longitudinal fashion for more additional length. Contraindications to vesico-psoas hitch include a small capacity or neurogenic bladder. Overall, durable long-term, ureteral patency has been seen with the use of vesico-psoas hitch [51].

Anterior Tubularized Bladder Wall Flap (Boari)

Ureteral injuries involving the lower two thirds of the ureter which cannot be bridged by a vesico-psoas hitch are suitable for an anterior

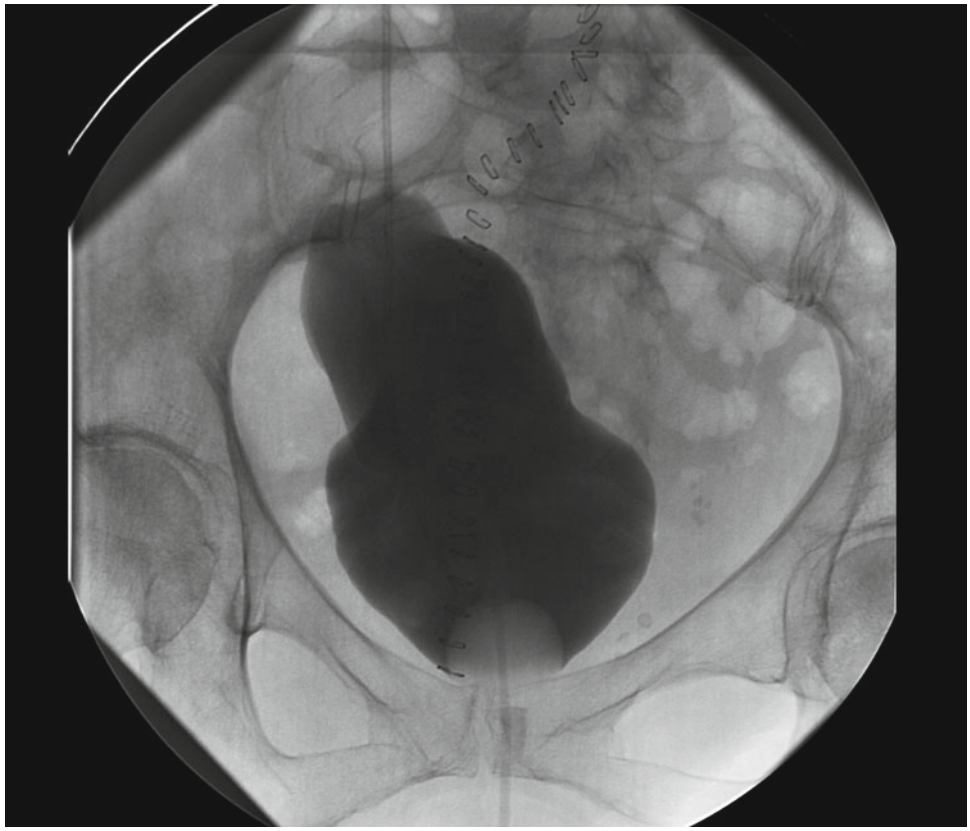

Fig. 4.5 Cystogram showing the postoperative findings of a right-sided vesico-psoas hitch. An indwelling ureteral stent shows the location of the ureter

tubularized bladder wall flap, or Boari flap [14, 30]. Contraindications to the procedure include a small capacity, irradiated, or neurogenic bladder. This repair is best reserved for an elective setting as it is time-consuming and not appropriate in hemodynamically unstable patient. The bladder is mobilized in a fashion similar to that described for a vesico-psoas hitch. The affected ureter is mobilized, debrided, and spatulated appropriately. A U-shaped incision is made in the anterior bladder wall. If additional length is required, then an L-shaped, spiral flap can be extended to the contralateral side [52]. The flap is created with a 4 cm base and a flap length to base width of less than 3:1 is used in order to preserve the flap blood supply and minimize ischemia (Fig. 4.6) [3]. The proximal bladder can be secured to the psoas tendon similar to a vesico-psoas hitch to reduce tension on the repair. A refluxing or non-refluxing ureteral anastomosis is performed with fine self-absorbable suture. The flap is then tubularized over a ureteral stent using absorbable suture. Ureteral defects of up to 15 cm can be repaired using this technique [53]. If additional length is required, the kidney itself can be mobilized by nephropexy and secured inferiorly. Series are limited but long-term outcomes have been successful [54].

Transureteroureterostomy

Injuries to the distal two thirds of the ureter are generally best managed with the above described techniques. Rarely is a transureteroureterostomy indicated except in the face of some other concomitant pelvic injury, pelvic

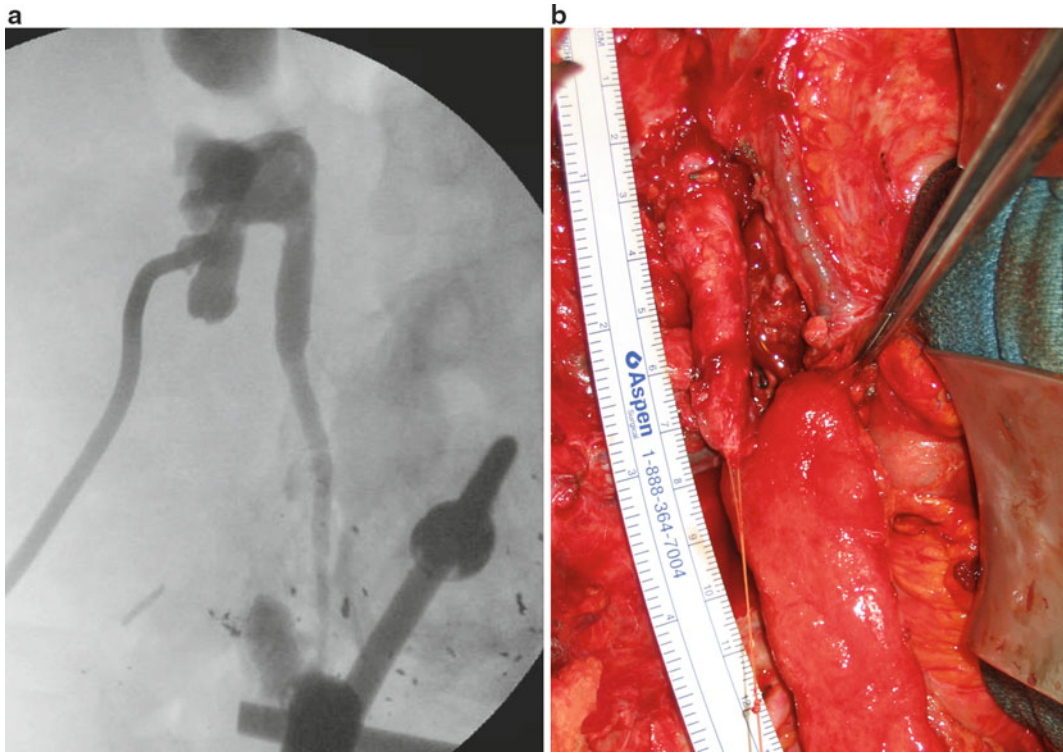

Fig. 4.6 (**a**) Preoperative antegrade nephrostogram demonstrating a gunshot wound with proximal right ureteral injury, spinal hardware, and multiple bullet fragments. (**b**) Intraoperative photograph of a mobilized ureter and anterior wall bladder flap prior to tubularization

scarring, or bladder abnormality preventing ureteral reimplantation or tubularized bladder flap. Contraindications to the procedure include a history of stone disease or upper tract transitional cell carcinoma. Care must be taken in appropriately selecting operative candidates as transureteroureterostomy can convert a unilateral traumatic ureteral injury into a bilateral iatrogenic one [3]. The injured ureter is mobilized and brought above the inferior mesenteric artery through a window in the retroperitoneum [55]. The recipient ureter is prepared with minimal mobilization to prevent injury. A 1.5 cm ureterotomy is made and a spatulated anastomosis is created. The donor ureter is stented across the repair into the recipient ureter distally. Modern series have shown successful long-term patency rates of greater than 95 % [56].

Ureteropyelostomy/ Ureterocalycostomy

Short, proximal ureteral injuries are best dealt with by performing a ureteropyelostomy. Many of these are seen in blunt injuries with rapid deceleration and penetrating wounds to the renal pelvis. The edges of the renal pelvis and ureter are freshened and closed in a watertight fashion with self-absorbable suture over a spatulated, stented anastomosis. Larger, more devastating injuries to the renal pelvis which prevent reanastomosis are better dealt with using a ureterocalycostomy. Injuries such as this type are often managed in a delayed fashion. If repaired acutely, the renal pelvis defect is closed to prevent urinary extravasation and the ureteral edges trimmed back to healthy bleeding edges. An inferior pole nephrectomy is performed revealing the inferior

calyx. Hydronephrosis with calyceal dilatation is useful as the calyx is small, making the anastomosis difficult to perform. The repair should be made with stented, spatulated, mucosa-to-mucosa anastomosis [53, 57]. The inferior pole is covered with surrounding tissue such as Gerota's fascia or an omental flap in order to prevent bleeding from the raw surface of the renal parenchyma. Ureterocalycostomy is used uncommonly in the trauma setting and has been reported to have higher rates of restenosis than other repairs [58, 59].

Long Ureteral Defects

Long ureteral injuries in which the majority of ureter is damaged require complex, time-consuming repairs. These should be approached in a delayed setting. The use of intestinal interposition segments and autotransplantation of the kidney to the pelvis are detailed in Chap. 21.

Postoperative Care

Postoperative Management

Ureteral repairs should be stented to maximize urinary drainage. Retroperitoneal drains are placed to prevent urinoma formation. Suction drains can result in continued urinary drainage due to negative pressure, so care must be taken not to place them directly adjacent to the repair. Drains may be removed in 48 h or after extravasation of urine decreases. For patients in which the peritoneum has been opened, a drain fluid creatinine can be obtained and compared to serum to differentiate the extravasation of urine from high output peritoneal fluid. Foley catheter drainage is a necessity to prevent reflux of urine up the ureteral stent and through the anastomosis. Traditionally, some authors advocate a suprapubic tube as additional drainage if the bladder has been opened, although the authors have not found that practice to be routinely necessary [4, 53]. Bladder drainage may be discontinued on day 2–10 depending on the type of repair performed. Those repairs involving opening the bladder favor the latter, with cystogram confirmation of complete bladder closure. The ureteral stent should be maintained for 4–6 weeks to assure adequate healing.

Patients are monitored for the overall success of the repair. Renal function should be followed with a basic metabolic panel. If ureteral injury is accompanied by renal injury or suspicion of renal compromise through prolonged obstruction, a radionuclide scan should be obtained. Contrast imaging using either CT-IVP, retrograde pyelogram, or intravenous pyelogram is used at 3 and 6 months to evaluate for stricturing of the repair [53]. The authors prefer to survey the patients with yearly ultrasound to monitor for new onset hydronephrosis and possible obstruction. Follow-up is often poor due to the transient nature of the trauma population [14].

Complication of Surgical Management

Up to 25 % of all ureteral repairs will result in complications [4]. The most common are prolonged urinary leakage at the site of repair. This can result in urinoma, peritonitis, abscess, or even sepsis. In the acute postsurgical setting, management includes continued stenting of the repair to facilitate ureteral healing and maintenance of retroperitoneal drainage. If stents were removed early in the postoperative course, they require replacement cystoscopically. Patients presenting in a delayed fashion with new onset of pain, fevers, ileus, and high output drainage from incisions or drains require reimaging to look for a urine leak and/or breakdown of the repair. Fluid collections, whether a urine leak or abscess, may require percutaneous drainage placed by interventional radiology. Any signs of infection should be managed with intravenous antibiotics. Persistent drainage, despite ureteral stenting, or high output drainage is tempered with the additional placement of a percutaneous nephrostomy to further divert the drainage of urine.

The most frequent long-term complication is stricture at the site of anastomosis. These are managed by endoscopic means if short segments

through balloon dilation or endopyelotomy. Little has been written on the endoscopic management of recurrent stricture after repair of traumatic injuries. However, a corollary is drawn from the management of iatrogenic ureteral injuries and recurrent ureteropelvic junction obstruction. Please see Chap. 21 for further details. Long or complicated recurrent strictures are typically treated with open revision using similar techniques to those already described above [30].

Conclusions

Traumatic ureteral injuries are rare and a high index of suspicion is warranted. Surgical exploration remains the gold standard for the detection of ureteral injury. Radiologic studies and the presence of hematuria are associated with poor sensitivity, resulting in delayed detection, leading to increased patient morbidity. Once discovered, a wide variety of ureteral reconstructive techniques must be customized to the individual patient. The repair of ureteral injuries is based on stability of the patient, injury mechanism, location of injury, and associated ureteral blood supply. Through judicious application of key principles of ureteral repair, a high rate of renal salvage can be obtained with successful long-term outcomes.

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Bladder Trauma

5

Lawrence L. Yeung and Steven B. Brandes

Incidence

Major bladder trauma accounts for less than 2 % of injuries requiring surgical exploration, and represents a minority of trauma visits to the emergency department (ED). Mortality can be as high as 22 % because of associated multiple organ injuries, rather than the extent of bladder injury [1]. Overall, roughly 60 % of bladder injuries are extraperitoneal, 30 % intraperitoneal, and 10 % occur concomitantly [2].

Blunt external trauma accounts for the majority of bladder injuries presenting to the ED, either from a direct blow to the abdomen or due to shearing forces. The most common cause of penetrating bladder injury is iatrogenic. Most of these injuries occur as a result of surgery, with the greatest incidence being from pelvic surgery. Injury can also occur (although rare) as a result of migration and erosion of foreign bodies, such as surgical drains, intrauterine devices, or chronic indwelling Foley catheters [3]. In the civilian population, penetrating trauma accounts for about 14–33 % of bladder rupture [1].

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Anatomy

The bladder in adults is an extraperitoneal organ that is well-protected deep within the retropubic space and is surrounded by the bony pelvis. Its anatomic position changes with its extent of distention. An empty bladder is bounded superiorly by the peritoneum, which passes into the median umbilical ligament. Inferolaterally, it is bounded by the pelvic floor fascia, levator ani musculature, and pelvic wall. Posteriorly, in males, it is bounded by Denonvillier's fascia and the rectum. In females, it is closely related to the anterior wall of the vagina. Lastly, at the neck of the bladder (where it opens to the prostate in males and the urethra in females), it is bounded anteriorly by the pubic symphysis and held in place by the puboprostatic or pubourethral ligaments [3].

As the bladder fills, the dome exits the protective confines of the retropubic space and rises to become an intraperitoneal organ. On overfilling, it can even reach the level of the umbilicus. Thus, if the bladder is full at the time of rupture, it is more likely to result in an intraperitoneal injury; an extraperitoneal injury is more likely when the bladder is empty. In children, the bladder is largely an intraperitoneal organ, thus making it more vulnerable to trauma. As the child grows, the pelvis enlarges, protecting the bladder from injury [3].

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Mechanism of Injury

Blunt injury to the bladder results from sudden deceleration in a high-speed motor vehicle crash or from an external blow to the lower abdomen. Seat belts can cause injury to a full bladder during a motor vehicle collision [4]. Intraperitoneal bladder rupture occurs in a fully distended bladder because the sudden increase in intravesical pressure from blunt lower abdominal trauma results in injury to its weakest portion, the dome. The dome of the bladder is protected only by the peritoneal reflection, resulting in bladder lacerations that are usually several centimeters long. An empty bladder is usually not injured, except by extraperitoneal shearing forces [2] (Fig. 5.1). Penetrating trauma occurs most commonly as a result of a GSW or stab wound to the bladder. There may be multiple sites of bladder injury and the degree of extravasation on cystography typically does not directly correlate with the severity of bladder injury.

In contrast, extraperitoneal bladder injuries are nearly always associated with a pelvic fracture. Injuries are commonly anterolateral and near the bladder base. Bladder perforation by a bony spicule is a rare event. Varying older studies conclude that the main mechanism of extraperitoneal bladder injury from blunt trauma is laceration from a bony fragment, because the sites of most (up to 76 %) of their bladder injuries were in proximity to the fracture site [5, 6]. In contrast, contemporary series have demonstrated that most bladder ruptures occur away from the pelvic fracture, as a result of a bursting-type injury or shearing force from the disruption of the ligamentous attachments of the bladder to the pelvis [1, 7]. Carroll and McAninch reported that 63 % of blunt injuries occurred in the dome or sidewall, 20 % were at the anterior or posterior bladder, and only 14 % of injuries were in proximity to the pelvic fracture (near to the bladder neck) [1]. Moreover, other contemporary series also reported that most areas of extravasation on cystogram were away from the site of pelvic fracture, and on exploration, bony spicules were never found at the site of bladder injury [7]. Extravasated urine is confined to the pelvis when the urogenital diaphragm is intact. When the superior fascia of the urogenital diaphragm (which is contiguous with Dartos, Colles', and Scarpa's fascia) is ruptured, urine can infiltrate the scrotum, perineum, and abdominal wall. When the inferior fascia is disrupted, urine can also infiltrate the penis or thigh [8].

Signs and Symptoms

All patients who present with lower abdominal trauma, blunt or penetrating, are at risk for bladder injury. Symptoms are typically nonspecific. Patients commonly complain of pelvic or lower abdominal pain and inability to void. Physical examination may identify lower abdominal bruising or tenderness over the suprapubic region or pubic symphysis. Other signs of potential bladder injury are abdominal distention, absent bowel sounds (secondary to an intraperitoneal bladder rupture and urinary ascites) or low urine output. Women with bladder rupture must undergo careful vaginal (pelvic) examination to identify concomitant vaginal or urethral lacerations or palpable bony spicules. Gross blood in the vaginal vault suggests such an injury and warrants a thorough examination. A digital rectal examination is essential to assess for rectal tone (loss of tone suggests spinal cord injury), blood in the rectal vault (suggests rectal laceration), palpable bony spicule or a "high riding" or non-palpable prostate (suggesting urethral injury). The associated large pelvic hematoma, however, often makes rectal landmarks indistinct and the prostate difficult to palpate.

The hallmark of bladder injury is hematuria. Gross hematuria is found in over 95 % of blunt bladder ruptures and the remaining 5 % have microscopic hematuria [1, 9]. In contrast, one-half of penetrating bladder injuries present with microscopic hematuria and the other half present with gross hematuria. A concomitant pelvic fracture injury may be the sole manifestation of a bladder injury. Pelvic disruption is associated with about 90 % of bladder ruptures, but only 9–16 % of pelvic fractures have a concomitant bladder rupture [2, 8].

Bladder ruptures that are initially missed and diagnosed late, often present with the signs of

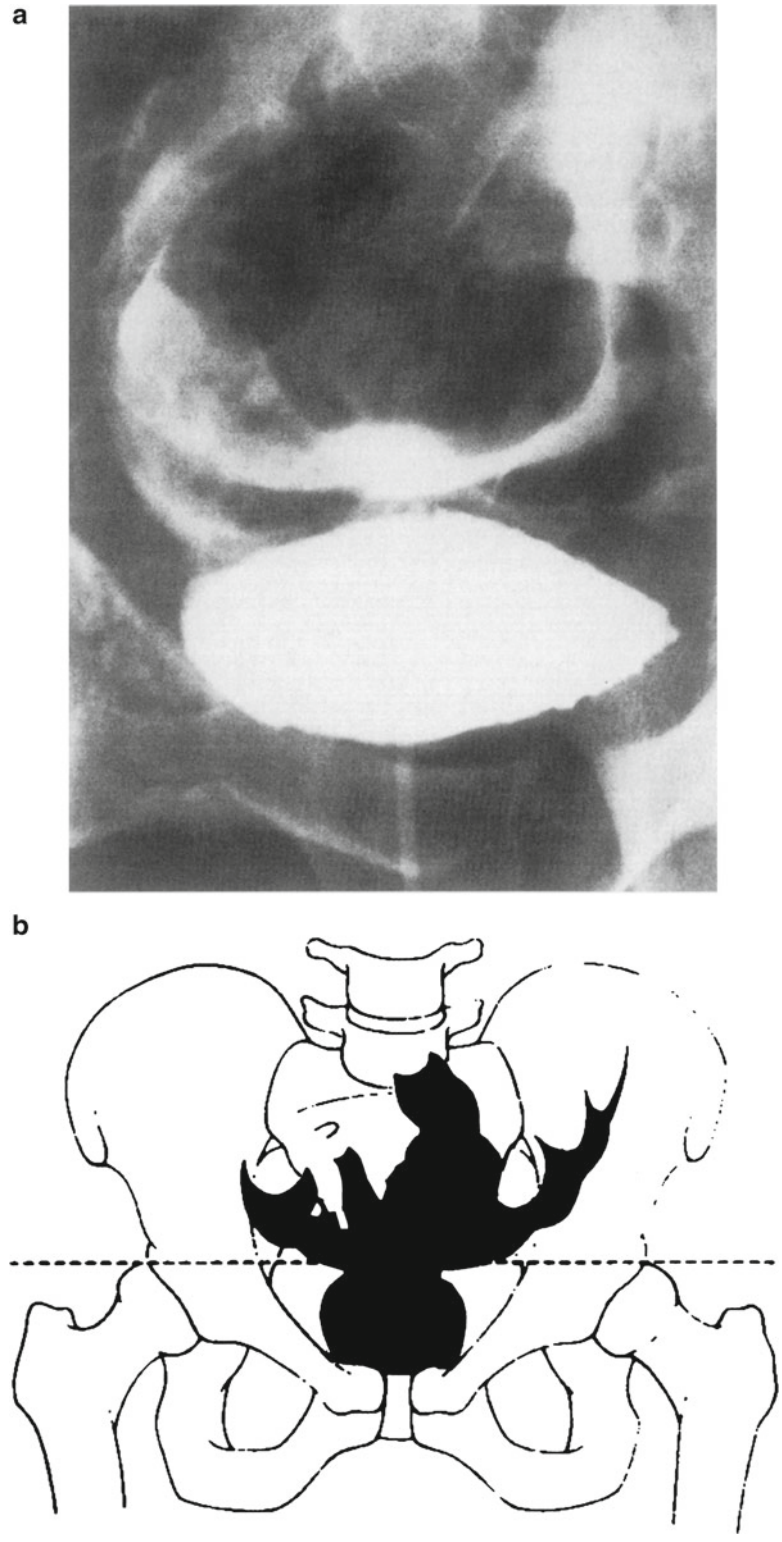

Fig. 5.1 (**a**) Cystography demonstrating an intraperitoneal bladder rupture by contrast extravasation outlining loops of bowel. (**b**) Illustration that intraperitoneal bladder rupture contrast extravasation is usually all above the superior margin of the acetabulum (reproduced with permission from Wyker and Gillenwater [41])

abdominal distention, hypoactive bowel sounds, or prolonged ileus and laboratory findings of elevated levels of serum blood urea nitrogen and/or creatinine, hyperchloremic metabolic acidosis, hypernatremia, or hyperkalemia [10].

Associated Injuries

Bladder injuries from external blunt trauma are rarely isolated, with 94–97 % having associated injuries, mainly pelvic and long-bone fractures, and head/spinal and visceral injuries. Mortality rates are high (16–53 %), primarily caused by severe pelvic fracture and pelvic hemorrhage, head injury, and late multisystem organ failure. Associated male urethral and renal injuries also occur, in 10 % and less than 2 % of bladder ruptures respectively. Most urethral injuries are type III posterior injuries. In women with a bladder injury or pelvic fracture, a thorough pelvic exam is important to determine any concomitant vaginal or urethral laceration. When GSWs cause bladder rupture, more than 80 % have associated visceral injuries [4].

Evaluation

Indications for Imaging

After penetrating trauma to the lower abdomen, all patients with microscopic or gross hematuria or a bullet trajectory in the path of the bladder should have imaging of the urinary bladder, either by CT cystogram or conventional cystography. In a recent meta-analysis of published retrospective series, gross hematuria and pelvic fracture are the only absolute indication for radiographic imaging of the bladder. Overall, 90 % of blunt bladder ruptures present with gross hematuria and 88 % present with a concomitant pelvic fracture [10]. The risk for bladder rupture in patients with gross hematuria and pelvic fracture is 29 %, while with microhematura or a normal urinalysis, the risk of bladder rupture is only 0.6 % [10]. Thus, relative indications for cystography include gross hematuria without pelvic fracture, microhematuria with pelvic fracture, isolated microhematuria, or free fluid in the pelvis and pelvic fracture [10]. In addition, Fuhrman et al. [11] argued that performing cystography only in patients who have gross hematuria is safe and provides a significant cost savings. The types of pelvic injuries that have been shown to be independently associated with bladder injury include diastasis of the pubic symphysis greater than 1 cm or fracture of the obturator ring with displacement greater than 1 cm [12].

When performed properly, either CT cystography or plain film cystography is highly sensitive and specific at identifying bladder injuries [13–15]. To avoid false negative results, formal retrograde bladder filling with contrast is necessary. Passive, antegrade bladder filling with Foley catheter clamping is unreliable due to inadequate bladder distention.

CT Cystography

Pelvic CT without contrast bladder filling is not accurate in diagnosing bladder injury [14]. Delayed films obtained after administration of intravenous contrast and passive filling of the bladder with Foley catheter clamping are not adequate because the bladder may not be completely distended, thus injuries can be missed [16]. However, when CT cystography is performed by retrograde instillation of contrast material into the bladder via a Foley catheter, it is equally as accurate and reliable as conventional cytography. At least 300 mL of a dilute contrast material must be instilled (i.e., 50 mL of Hypaque in 450 mL of normal saline) and the catheter clamped [17]. Spiral pelvic CT is then performed. Post-drainage films are not needed, since the CT scan can accurately image the posterior bladder when the bladder is full of contrast.

Further advantages of CT cystography over plain film cystography are that it can be combined with other CT imaging assessing for associated injuries to the head, chest, abdomen, or pelvis; has 100 % specificity and 100 % sensitivity [18]; and can be easily be performed in 10 min, at the same time as other CT studies, which saves time and saves the

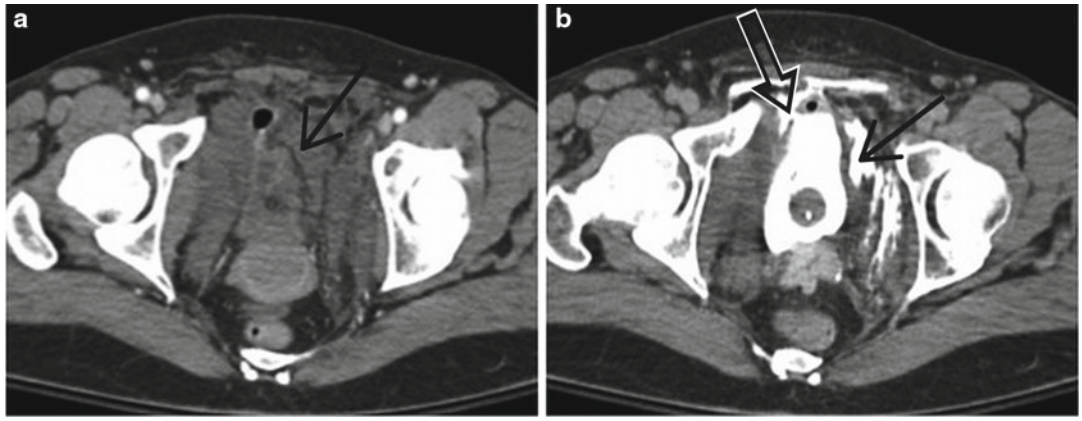

Fig. 5.2 CT cystography of an extraperitoneal bladder injury. (**a**) Note free fluid in the pelvis and space of Retzius (*arrow*) on the noncontrast CT. (**b**) Note contrast leak into the anterior abdominal wall (*open arrow*) and space of Retzius (*arrow*)

patient (with a potentially unstable pelvic or spine fracture) from transfer to the fluoroscopy suite for a second imaging study. Interpreting CT cystography is also less affected by overlying bone fragments caused by pelvic fracture, spine boards, or military antishock trousers. CT also provides more information about the surrounding pelvic structures and can more accurately assess the associated pelvic hematoma volume and extent [15]. Therefore, we advocate CT cystography over conventional plain film cystography to evaluate for bladder injuries. See images illustrating extraperitoneal (Figs. 5.2 and 5.3) and intraperitoneal (Figs. 5.4 and 5.5) bladder injuries diagnosed by CT cystography.

Conventional Cystography

A proper conventional cystogram is performed by filling the bladder with dilute contrast via a Foley catheter, under gravity to at least 300 mL or until contrast extravasation (in adults) or to urgency or leakage around the catheter (in children). Films are taken before filling, when the bladder is full, and after the contrast is drained and the bladder empty. Films in at least two projections are preferred, but are often not possible because of concomitant pelvic fracture. Inadequate bladder filling is demonstrated by folds in the bladder lining. Post-drainage films are essential to avoid missing roughly 13 % of injuries, especially for small extraperitoneal bladder lacerations and for penetrating bladder injuries [13, 14]. The sensitivity and specificity for plain film cystography is 95 % and 100 %, respectively [19]. The degree of contrast extravasation does not commonly correspond to the extent of bladder injury. Because of the importance in managing bladder neck injuries at the time of the occurrence, the cystogram should also adequately define the integrity of the bladder neck.

Findings on cystography that distinguish each bladder injury are as detailed below:

(a) *Bladder contusion* is a bladder mucosa or muscle wall injury without loss of wall continuity. The bladder outline is commonly distorted, but there is no contrast extravasation. The diagnosis is mainly one of exclusion, with no noted associated upper tract injury (normal abdominal CT or intravenous pyelogram) and urethral injury (normal retrograde urogram) to explain the presenting hematuria.

(b) *Interstitial bladder rupture* is a tear of the bladder wall that is not full thickness. The bladder outline is commonly distorted, but there is no extravasation of contrast.

(c) *Intraperitoneal bladder ruptures* are distinguished by contrast extravasation, which outlines loops of bowel, or fills the cul de sac or paracolic gutters. Such contrast extravasation is usually all *above* the superior margin of the acetabulum (Fig. 5.1).

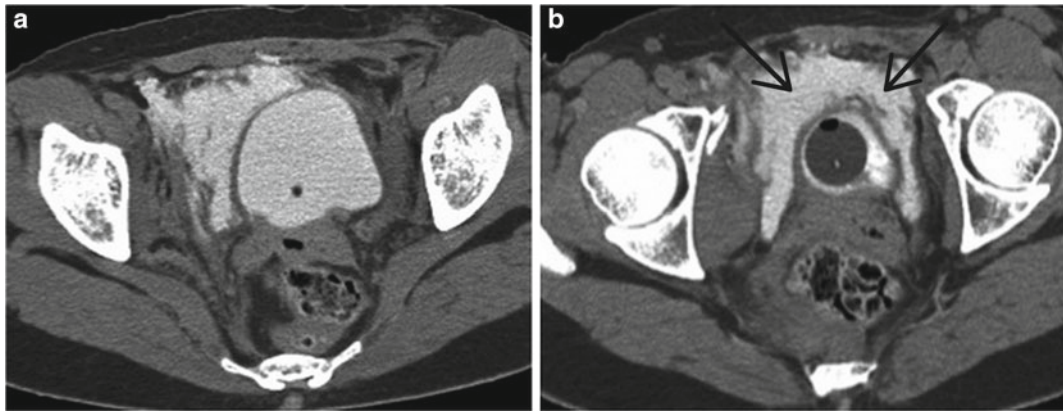

Fig. 5.3 CT cystography of an extraperitoneal bladder rupture. (**a**) Note contrast extravasation in the space of Retzius. (**b**) Typical "Molar tooth" sign—of fluid contained in space of Retzius (see *arrows*). Note no contrast in the cul de sac = extraperitoneal injury (images courtesy of C. Menias)

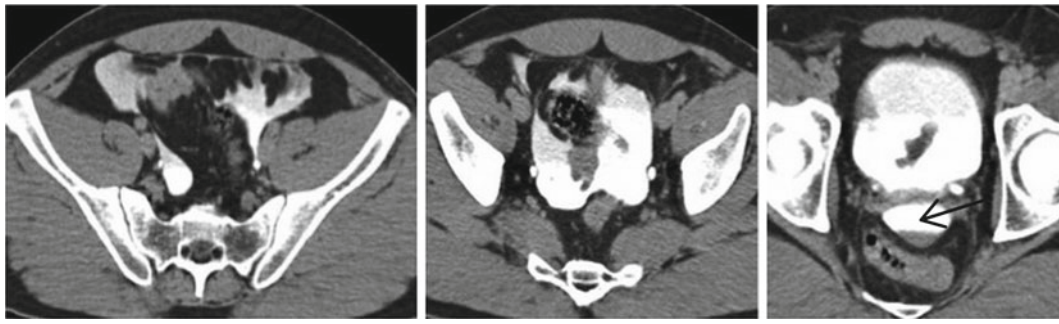

Fig. 5.4 CT cystography of an intraperitoneal bladder injury. Free Intraperitoneal fluid surrounding bowel loops, indicating an intraperitoneal bladder injury. Also note fluid in cul de sac (*arrow*)

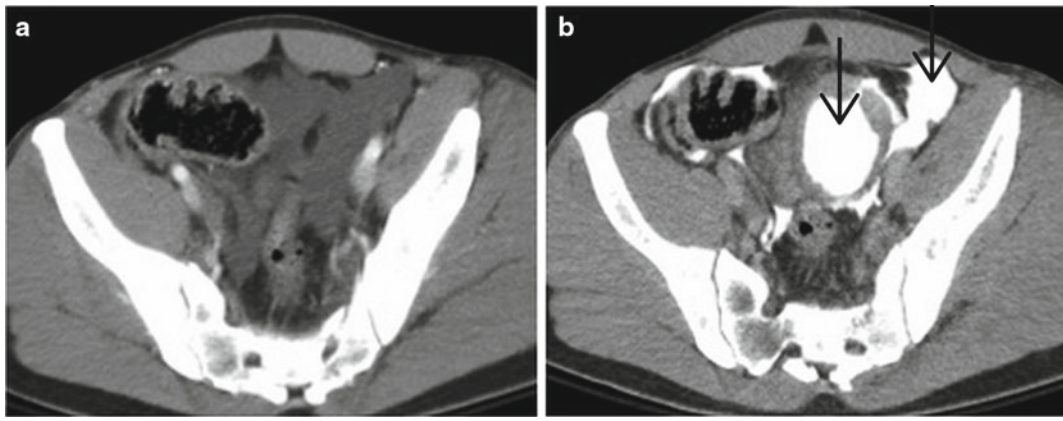

Fig. 5.5 CT cystography of an intraperitoneal bladder injury. (**a**) Free fluid in paracolic gutters and cul de sac outlining bowel (*arrows*). (**b**) Note opacification of free fluid during cystogram (*arrows*) (images courtesy C. Menias)

Fig. 5.6 Illustration of the starburst contrast extravasation pattern of extraperitoneal bladder ruptures. Note that contrast extravasation is typically below the superior margin of the acetabular line (reproduced with permission from Wyker and Gillenwater [41])

(d) *Extraperitoneal bladder ruptures* are characterized by flame-like or starburst shaped contrast extravasation. Typically, such contrast extravasation is all *below* the superior margin of the acetabular line (Fig. 5.6).
(e) *Large pelvic hematomas* typically result in a "teardrop"-shaped bladder due to the pelvic hematoma compressing the bladder from both sides. Aside from elongation, the bladder is lifted out of the pelvis. The degree of bladder distortion often corresponds to the severity of the pelvic hemorrhage (Fig. 5.7).

Focused Assessment with Sonography for Trauma

Focused assessment with sonography for trauma (FAST) is one of the most rapid studies for identifying hemorrhage or potential hollow viscus organ injury (i.e., bladder). With an experienced operator, the accuracy of FAST at detecting intraabdominal fluid is comparable to a diagnostic peritoneal lavage and abdominal pelvic CT. As part of the FAST scan, the pelvis and pouch of Douglas are examined for free fluid. After the initial scan, a second, or "control," scan is often done 30 min later. Pelvic fluid found on ultrasound and the presence of an associated pelvic fracture often warrants further imaging.

Classification

Bladder injuries can be divided into five types based on the extent of injury seen radiographically (traditionally by plain film cystography) and have been extrapolated to similar findings on CT cystogram [20].

Type 1 injuries are defined as a bladder contusion. Radiographic imaging is either normal or the bladder medially deviated because of an extravesical pelvic hematoma [20, 21].

Type 2 injuries present as an intraperitoneal rupture. Radiographically, contrast may be seen outlining bowel loops. On CT, contrast can be seen between mesenteric folds or in the paracolic gutters [17].

Type 3 injuries are defined as interstitial bladder injuries, with contrast dissecting into the bladder wall.

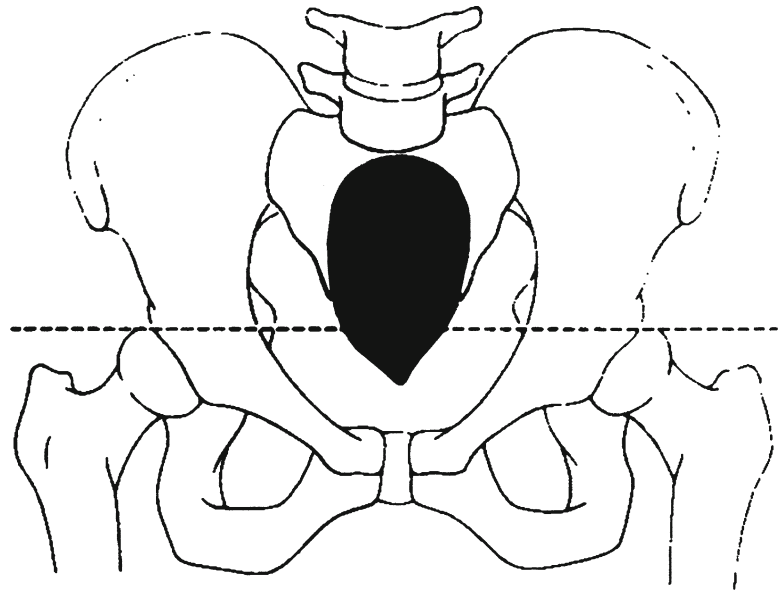

Fig. 5.7 Illustration of the cystographic appearance of the classic "teardrop"-shaped bladder due to pelvic hematoma compression of the bladder from both sides. Aside from being elongated, the bladder is lifted out of the pelvis

Table 5.1 Organ injury scale for bladder injuries

AAST grade	Bladder injury
Grade I	Bladder contusion, intramural hematoma, or partial thickness laceration
Grade II	Extraperitoneal bladder wall laceration <2 cm
Grade III	Extraperitoneal (>2 cm) or intraperitoneal (<2 cm) bladder wall laceration
Grade IV	Intraperitoneal bladder wall laceration >2 cm
Grade V	Intra or extra peritoneal bladder wall laceration extending into the bladder neck or ureteral orifice (trigone)

AAST American Association for the Surgery of Trauma

Type 4 injuries show an extraperitoneal bladder rupture in which contrast is seen in the perivesical space. On plain cystogram, evidence of an extraperitoneal rupture may be seen on the post-drainage films only, especially if the rupture is posterior to the bladder.

Type 5 injuries are concomitant intraperitoneal and extraperitoneal injuries. Contrast will be seen both retropubically in the prevesical space and intraperitoneally outlining loops of bowel.

The other commonly employed bladder injury grading system is the Organ Injury Scale of the American Association for the Surgery of Trauma [22]. The advantages of this grading system are that it has correlation between grade and injury severity, and it has predictive value regarding potential morbidity (the Organ Injury Scale is used to calculate the Abbreviated Injury Scale and Injury Severity Score; see Table 5.1).

Management

The evaluation and treatment methods we employ for lower urinary tract trauma are summarized in Fig. 5.8. The true size and number of intraperitoneal ruptures can only be reliably assessed by surgical exploration, not by cystography. For penetrating injuries, each missile tract should be explored, all foreign bodies and debris removed, all devitalized tissue debrided, and the cystotomy closed. In iatrogenic penetrating injuries, the entire bladder should be thoroughly inspected for additional sites of injury. Recently, some have reported laparoscopic repair of isolated intraperitoneal bladder ruptures with 100 % success rates [23].

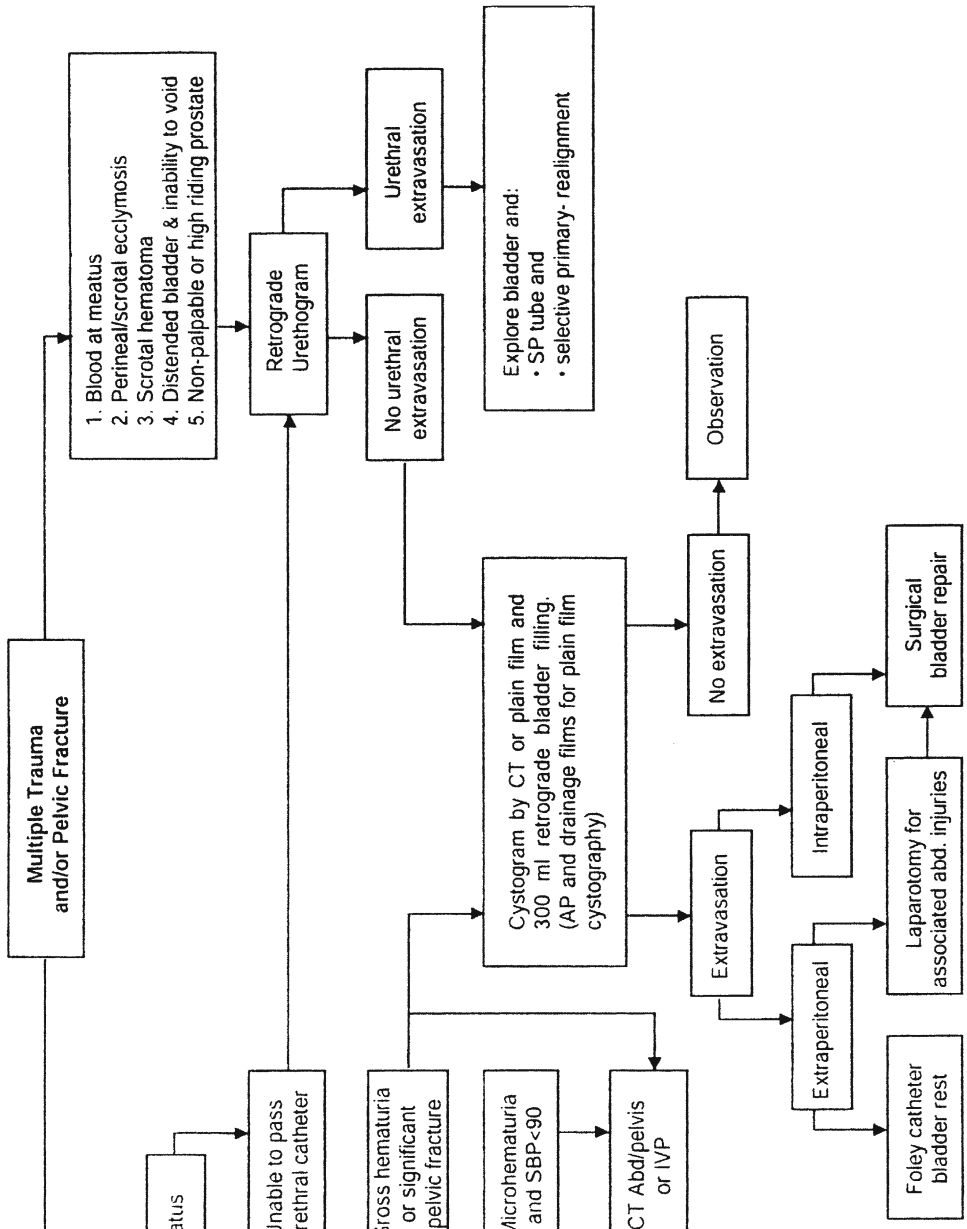

Fig. 5.8 Evaluation and treatment methods for blunt lower urinary tract trauma

After formal bladder repair, the urine can be diverted with either a Foley catheter or suprapubic tube. Large bore catheters are used to facilitate drainage of bloody urine and prevent clots from obstructing the catheter. Recent prospective studies demonstrate that, for repaired intraperitoneal bladder ruptures, urethral catheterization alone is adequate to provide bladder drainage and is associated with shorter hospital stay and lower morbidity. Thus, suprapubic tube placement is typically unnecessary and more morbid [24]. Additionally, many orthopedic surgeons feel that suprapubic tubes should be avoided whenever possible because they compromise anterior exposure for internal fixation of an associated bladder injury and may increase the rate of pelvic and hardware infection [25]. However, there is no literature to support this notion that suprapubic tube placement increases the risk of hardware infection. If both catheters are placed, then the Foley is usually removed once the urine clears. After 10–14 days, the suprapubic tube or Foley is commonly removed after cystography is performed.

Blunt extraperitoneal bladder injuries or interstitial ruptures that are isolated injuries can be successfully managed solely by Foley catheter drainage. As long as the patient has uninfected urine and appropriate catheter care, all patients with an extraperitoneal bladder injury can be managed with simple catheter drainage, despite the amount of extravasation seen on cystography [7]. All patients managed nonoperatively should have a large bore suprapubic tube or Foley catheter placed and maintained on prophylactic antibiotics to cover both Gram-positive and Gram-negative bacteria to prevent infection of the pelvic hematoma. The evidence to support the practice of prophylactic antibiotics is borne from retrospective case series [26]. While no formal recommendations have been developed to recommend the type or duration of antibiotic use, it seems logical that Gram-positive and Gram-negative coverage should continue until healing of the bladder injury has been demonstrated.

The greatest risks to proper and expeditious healing are a urinary tract infection or bladder distention from inadequate bladder drainage [26]. Most patients have concomitant pelvic hematomas and improper drainage can lead to bacterial colonization of the hematoma, abscess formation, and poor bladder wall healing. After 10–14 days of drainage, retrograde cystography should be performed to evaluate for persistent urinary extravasation. Spontaneous healing occurs in 74–87 % of patients after 2 weeks of bladder rest [7, 26]. Another 11–13 % will heal with prolonged drainage for 2–13 weeks.

Patients at greatest risk for impaired healing include those with more severe concomitant injuries, worse pelvic fractures, and a higher transfusion requirement [26]. However, when the abdomen is explored for associated injuries, most recommend that extraperitoneal bladder ruptures also be repaired at the same time [23]. Also, if the patient was too unstable for cystography, but intraoperatively there are suggestions of a bladder injury, the bladder should be explored. The bladder should be exposed through a midline abdominal incision, with the bladder opened at the dome, to avoid the lateral pelvic hematomas. Opening the pelvic hematoma may cause bacterial contamination and release the tamponade effect. Bladder lacerations are then oversewn from within the bladder. The bladder neck and ureteral orifices also need inspection for possible injury. If the patient is found to have a bladder neck injury, then the pelvic hematoma may have to be entered in order to achieve adequate exposure for repair. To assess for ureteral integrity, the ureteral orifices can be gently cannulated with a pediatric feeding tube or observed for blue urine after the administration of intravenous indigo carmine. To avoid potential contamination of the pelvic hematoma, most surgeons do not place drains. However, there is no evidence to support this concern for infection. Regardless, the use of a closed suction drain is well tolerated, even in the presence of orthopedic hardware.

All bladder lacerations that extend into the bladder neck demand formal and prompt repair. If these types of injuries are left unrepaired, the majority of individuals will have a fixed internal sphincter and risk post-injury stress incontinence. Other indications for immediate repair include concomitant urethral disruption (that precludes urethral catheterization) and/or rectal injury.

All intraperitoneal bladder ruptures should be explored either through a lower midline incision or a formal laparotomy incision if other intraabdominal injury is suspected. The injury at the dome of the bladder is obvious and often up to 6 cm long. The bladder should be visually and palpably inspected for signs of any other injury. Any areas of devitalized tissue should be excised, and all lacerations identified should be closed in two layers with absorbable suture [1]. The bladder should be drained with a suprapubic tube or Foley catheter. If the bladder closure is inadequate and gross hematuria severe, a suprapubic tube can also be placed through a separate cystotomy and brought out obliquely through a separate skin incision.

On abdominal exploration, if persistent and uncontained pelvic bleeding is found, "damage control" management of the bladder rupture should be employed. Damage control entails a staged, planned reexploration with the pelvis packed, abdomen closed, and the bleeding pelvic vessels embolized in the angiography suite. Ligating the hypogastric arteries or attempting to find any venous bleeding is of little benefit in controlling bleeding and often releases the tamponade effect. After 24–48 h of stabilization in the intensive care unit, the patient should be reexplored and the laparotomy packs removed. During that time, Foley catheter drainage is often sufficient to divert the majority of the urine.

Iatrogenic Injuries

The bladder is the most frequently injured organ during pelvic surgery. The greatest risk factors for iatrogenic injury to the urinary bladder are poor visibility and anatomic distortion. Such risk factors are typically present with large pelvic masses, a gravid uterus, obesity, pelvic hemorrhage, malignant disease, inadequate surgical exposure, small incision size, or poor wound illumination. The risk factor of anatomic distortion may occur as a result of adhesions/previous pelvic surgery, pelvic organ prolapse, congenital anomalies, radiation therapy, chronic inflammatory pelvic disease, endometriosis, malignant infiltration, or a distended, thin-walled bladder. Table 5.2 provides a detailed list of bladder injury by surgical procedure [21].

Table 5.2 Incidence of bladder injury by surgical procedure

Surgery	Per 1,000 procedures
Vaginal delivery	0.1
Cesarean section	1.8
Gynecological surgery (open)	1.5
Vaginal hysterectomy	9
Radical cancer hysterectomy	14
Obstetric hysterectomy	61
Gynecological surgery (laparoscopic)	3
Laparoscopic assisted vaginal hysterectomy	28
Transurethral resection of a bladder tumor	25
Bladder neck suspension	9
Inguinal herniorraphy	1.5

Adapted from [21], with permission

Bladder injury during a surgical procedure may be evident by clear fluid draining into the operative field or a visible laceration of the bladder. When bladder injury is suspected, all bladder walls should be thoroughly inspected. Another method to assess for bladder injury is by retrograde filling of the bladder with methylene blue-tinged saline. Blue dye in the pelvis indicates a bladder laceration. Cystoscopy can be performed, particularly to assess the location of the bladder injury and proximity to the trigone or ureteral orifices. To facilitate locating the bladder injury, if the abdomen is already open, the bladder can be opened at the dome and explored. Bladder injuries in proximity to the ureteral orifices may require ureteral stenting or ureteral reimplantation.

When a bladder injury is discovered during pelvic surgery, it is wise also to investigate for a concomitant ureteral injury. Direct inspection of the surgically exposed ureter or after indigo carmine administration is often sufficient and prudent. If the patient had received prior pelvic irradiation such as for cervical cancer, bladder suture lines should be covered with omentum or peritoneum (if available) to prevent possible fistulization.

Principles for bladder management and repair of iatrogenic injuries are the same as for external trauma. Bladder decompression by Foley catheter is typically for 7–14 days. A suprapubic tube is generally unnecessary unless there is considerable gross hematuria that could obstruct the catheter. A suction drain is often placed in the prevesical space for a few days until drainage is minimal. If drainage output remains high, the drainage fluid should be sent for creatinine concentration. Creatinine levels greater than serum indicate a urine leak; Levels equal to serum indicate peritoneal or lymphatic fluid. Persistent leakage typically resolves with prolonged bladder drainage with the pelvic drain taken off suction and placed to gravity drainage [27].

Undiagnosed intraoperative injuries to the bladder typically present days to weeks after surgery. In patients with prior pelvic irradiation, fistulas can present months to even years after hysterectomy. Typical signs of missed injury include hematuria, oliguria, an elevated serum BUN/creatinine ratio, lower abdominal pain and distension, peritonitis or sepsis, or a urinary fistula. When signs and symptoms suggest a missed bladder injury, CT or plain film cystography with drainage films should be performed as described above.

Abdominal Hysterectomy

In gynecologic surgery, bladder injury most commonly occurs during abdominal hysterectomy. The bladder can be injured at four specific sites: (1) on incising the parietal peritoneum; (2) entering the vesicouterine fold; (3) separating the bladder from the uterine fundus, cervix, or upper vagina; or (4) entering the anterior vagina or upon mobilization or suturing of the vaginal vault (Fig. 5.9). If a bladder injury is noted at this time, it can usually be easily managed by a two or three layer closure with absorbable suture and Foley catheter bladder drainage. Retrograde bladder filling with blue-colored saline can facilitate in the diagnosis of a bladder injury.

Vaginal Surgery

Most bladder injuries during vaginal hysterectomy are in the supratrigonal area of the bladder base and rarely involve the trigone. Anterior colporrhaphy and stress incontinence surgery bladder injuries typically involve the floor and/or the trigone. Thus, integrity of the ureteral orifices and the proximity to the injury must be assessed. For such bladder injuries, cystoscopy is helpful to identify the location of the injury. If there is any suspicion for a concomitant ureteral injury, intravenous indigo carmine should be given and the ureteral orifices observed for blue dye. Once ureteral injury is excluded, the bladder injury can be repaired in two or three layers transvaginally. Transvaginal closures require a watertight closure and nonoverlapping suture lines for the vaginal and bladder closures to prevent fistula formation. A tenuous closure or a radiated pelvis should have tissue interposed (i.e., Martius flap), if possible. The adequacy (watertightness) of the bladder closure can be tested by retrograde filling of the bladder with saline. A Foley catheter is typically left indwelling for 7–14 days. After the bladder laceration has been repaired, the vaginal surgery can be completed.

Laparoscopy

Laparoscopic procedures have a 2–10-fold greater risk of bladder injury than the open surgical counterpart. When injured, the bladder is usually penetrated on initial placement of the Veress needle or trocar (typically by trocar placement in the midline and lower abdomen). Trocar injuries are typically to the bladder dome, and have entry and exit wounds. Laparoscopically, bladder injuries occur most often with a full bladder or a bladder with distorted anatomy from previous pelvic surgery, endometriosis, or adhesions [28].

Intraoperatively, the diagnosis of bladder injury is suggested by the presence of gas insufflation of the Foley bag or gross hematuria. Other signs of injury are urinary/fluid drainage from an accessory trocar site, or fluid (urinary

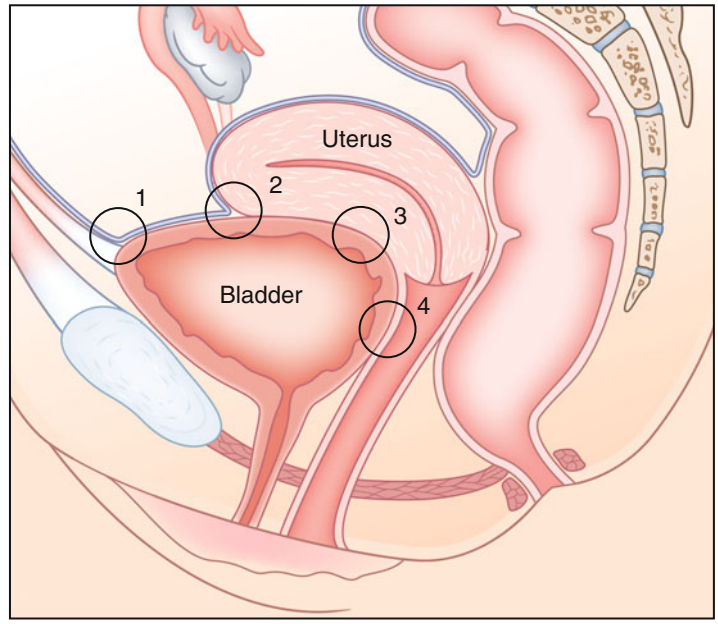

Fig. 5.9 Midsagittal view of the female pelvis demonstrating the four areas typically at risk for bladder injury during abdominal hysterectomy: *1* parietal peritoneum; *2* vesicouterine fold; *3* bladder-uterus plane; *4* vaginal vault

ascites) pooling in the abdomen/pelvis. Because of the pneumoperitoneum, the borders of the bladder tear are often easy to visualize because the bladder is also distended from the insufflating gas [29]. If the bladder injury site is not obvious, the bladder should be filled retrograde with methylene blue-colored saline. Extravasation of dye notes an intraperitoneal bladder injury [28, 29]. Veress needle injuries and other small injuries to the bladder can be successfully managed conservatively by prolonged catheter drainage followed by cystography. Large bladder injuries, such as by trocar or surgical dissection, require suturing the injuries closed (either laparoscopically or by open repair). Laparoscopic repair of such bladder injuries should be performed only if the laceration is small, there is adequate exposure and visualization of the cystotomy, the ureters and bladder neck are not compromised, and the surgeon has adequate expertise in intracorporeal suturing [28, 29].

Augmentation Cystoplasty Rupture

Augmentation enterocystoplasty has been an effective method to achieve urinary continence for patients with poorly compliant, low-volume, neurogenic bladders. Typically, such patients are children with myelomeningocele or adults with neurologic disorders such as multiple sclerosis or spinal cord injury. However, since they are frequently insensate, if the augmented bladder is not drained frequently it can become over-distended and rupture.

Usually, signs of rupture include abdominal pain with rebound tenderness, decreased or absent bowel sounds, or microscopic or gross hematuria [30]. Many symptoms are nonspecific and may vary from shoulder pain (caused by diaphragmatic irritation from extravasated urine) to septic shock. Radiographic studies often do *not* show any urinary extravasation. In only one-half of cases will a cystogram demonstrate urinary extravasation [31, 32]. Others have reported that ultrasound and computed tomography are more likely to show extravasation than conventional cystography [33]. However, it is difficult to differentiate between extravasated urine and cerebrospinal fluid, which is seen with most patients with meningomyelocele (i.e., because of a ventriculoperitoneal shunt) [32]. Therefore, radiographic imaging is unreliable, and a high index of suspicion is required to diagnose an augmented bladder rupture. The decision to explore the abdomen is often based on the clinical history and physical exam and not radiological imaging.

Enterocystoplasty rupture may occur as a result of catheter trauma, chronic infection, or chronic overdistention. Rupture can also result from blunt trauma to the abdomen [31, 32]. Bladder rupture may occur as a result of ischemia in parts of the bowel after detubularization. As the bladder is chronically distended, areas of vascular insufficiency can weaken the wall, and lead to delayed rupture of the bladder wall [30].

The gold standard treatment for augmentation cystoplasty rupture is surgical exploration [30–32]. Management includes broad-spectrum antibiotics, identification and repair of the laceration, catheter drainage, and placement of a prevesical drain [31]. In highly select cases, catheter drainage alone (without surgical intervention) can be attempted. There are case reports of successful conservative management with serial abdominal exams, broad-spectrum intravenous antibiotics, and catheter drainage for stable patients without peritoneal signs. However, for patients who do not improve within 48 h or who have peritoneal signs, abdominal exploration is warranted [32].

Neobladder Rupture

In the last decade or so, continent, orthotopic bladder replacement has become a common surgical operation for patients undergoing radical cystectomy for bladder cancer. Up to 20 % of patients with a neobladder are unable to void by Valsalva and require clean intermittent catheterization. Rupture occurs as a result of overdistention of the neobladder either from mucus plug or infrequent catheterization. The neobladder wall may be weakened from ischemic changes to the detubularized bowel segment, transmural infection, or intraperitoneal adhesions resulting in impaired flexibility [34]. Usual sites of perforation include the dome or upper sidewall, which have a compromised blood supply and lack mesenteric support [34, 35].

Presenting signs and symptoms and efficacy of cystographic imaging for diagnosing rupture are the same for both augmented bladders and neobladders. Management of neobladder rupture involves exploratory laparotomy and repair of the injury. All areas of devitalized bowel should be excised and primarily repaired [35]. Anecdotal reports of conservative management with catheter drainage alone have been described in stable patients, along with broad-spectrum antibiotics and bowel rest [36]. Conservative management, however, is clearly not the standard of care because Fournier's gangrene and death have also been reported with nonoperative management [37].

Complications of Bladder Trauma

After bladder injury repair, long-term voiding dysfunction is usually not significant [14, 26]. The most common complications after repair include urinary tract infections and bladder spasms. However, more severe complications can occur, including incontinence, abscess formation, or fistula formation.

Incontinence

Lacerations away from the bladder neck may lead to transient urge incontinence once the Foley catheter is removed. Urgency is often caused by bladder mucosal irritation from the wound itself or the indwelling catheter and balloon, and usually only lasts for several days. Transient stress incontinence may also occur in women and usually lasts a few days or weeks [1].

Injuries involving the bladder neck, especially if it extends into the membranous urethra, can result in total urinary incontinence, especially in women. Bladder neck injuries are diagnosed by cystography or by direct exploration by palpation or visualization. All bladder neck injuries, therefore, should be repaired carefully with interrupted sutures around a Foley catheter. Persistent incontinence after bladder trauma should be evaluated with a careful voiding history, physical examination, cystoscopy, and urodynamic testing. Improvement in urinary control can occur for up to 1-year post injury. Thus, surgical intervention should be postponed until after that time. In patients who fail conservative management (pelvic floor training) or medical

therapy (with α-adrenergic agonists), continence may be achieved with an artificial urinary sphincter or urethral sling. Bulking agents to the bladder neck typically have poor durable results (particularly because the incompetent bladder neck is scarred) [14].

Pelvic Infection/Abscess

Overall, up to 6 % of patients develop an abscess after bladder trauma [1]. Abscess usually occurs as a result of infection of the pelvic hematoma in association with pelvic fracture. In patients with extraperitoneal rupture who are managed with Foley catheter alone, abscess may occur as a result of retrograde colonization of the hematoma from the catheter and urinary leakage [26]. This risk is minimized by keeping the patient on broad-spectrum antibiotics and using a large bore catheter (greater than 22 Fr) to maximally drain the bladder. If a pelvic infection is suspected after catheter removal, the patient should be placed on broad-spectrum antibiotics and the size and location of the abscess determined by computed tomography or ultrasound [14]. In male patients, epididymoorchitis may occur as a result of prolonged transurethral catheterization. We minimize this complication by placing a suprapubic tube and a Foley catheter. The Foley catheter is removed as soon as the urine clears.

Fistula

Urinary fistulas often develop as a delayed complication after bladder injury. This can be due to an unrecognized bladder injury, improper bladder repair, or suture breakdown due to infection. Additional risk factors for fistula formation include bladder outlet obstruction, urethral stricture disease, neurogenic bladder, diabetes mellitus, long-term steroid use, malignancy, prior pelvic irradiation, or foreign body presence [14, 38].

Vesicovaginal fistulas (VVF) may form as a result of concomitant vaginal laceration at the time of bladder injury. Each woman who presents with a pelvic fracture, bladder injury, or blood in the vaginal vault should undergo a thorough pelvic examination, speculum examination, or vaginoscopy to rule out a vaginal wall injury. If a vaginal injury is found it should be closed in two layers, usually in the lithotomy position. Concomitant bladder injury should be closed in two layers from within the bladder because exposure is better, and the ureteral orifices can be visualized [14, 39].

Bladder fistulas are typically recognized in a delayed fashion with painless, constant incontinence. Severity of the leakage is proportional to the size and location of the fistula. Diagnosis can be made by simultaneous retrograde bladder filling, cystoscopy, and vaginal speculum examination. In addition, a standard "pad" test can be performed with methylene blue instilled in the bladder, oral Pyridium, and pads or tampons placed in the vagina to evaluate for staining of the pads. Upper tract imaging should also be performed to rule out a ureteral injury. If there is a high index of suspicion for a ureterovaginal fistula or the urogram is equivocal, a retrograde ureterogram should be performed [14]. VVFs, when small and oblique, can sometimes be successfully managed with catheter drainage alone. Most posttraumatic VVFs, however, require surgical repair, after 3–6 months of tract maturing. If the fistula is diagnosed early (typically within 48 h after injury), immediate repair can be performed. In addition, if possible, omentum, peritoneum, or labial fat pad (Martius flap) should be interposed between the lacerations for maximal prevention of fistula formation [14, 40].

Vesicocutaneous fistulas can also occur, usually along the tract of a prior suprapubic site. Other commonly occurring nonhealing bladder fistulas are caused by foreign body, penetrating bony spicule, or bladder entrapment from pelvic fracture. Bladder fistulas usually close with prolonged Foley catheter bladder rest, unless they are very large, contain a foreign body, or there is significant obstructive voiding dysfunction. Persistent fistulas require formal excision of the fistula tract, bladder repair, removal of the foreign body (i.e., bony spicule); correction of any outlet obstruction is warranted.

Summary

Bladder injuries typically occur as the result of external force and are often associated with pelvic fracture, and/or gross hematuria. Iatrogenic injuries may result from gynecological or other extensive pelvic procedures. Reliable imaging for bladder rupture entails conventional cystography with adequate filling and postdrainage films, or retrograde bladder filling and CT cystography. Most extraperitoneal bladder injuries can be managed effectively by prolonged bladder drainage with a catheter. Intraperitoneal bladder or bladder neck injuries demand prompt exploration and repair. On repairing bladder injuries, the midline pelvic hematoma should be avoided, and simple bladder lacerations typically closed from within.

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Urethral Trauma

6

Daniel Dugi III and Allen F. Morey

Introduction

Urethral injuries are uncommon yet potentially devastating, often leading to sequelae such as stricture, impotence, infertility, and incontinence. Anterior urethral trauma most often occurs in conjunction with straddle-type injuries to the perineum; the fixed bulbar urethra is crushed against the pubic ramus. The penile urethra is less susceptible to traumatic injury because of its mobility, although penile injury during intercourse may involve the urethra. Posterior urethral injuries are those located near the external sphincter mechanism, occurring almost exclusively as a result of pelvic fracture. Urological management differs depending on the location of injury but must always secure reliable bladder drainage. Methods of diagnosis and *immediate* treatment of anterior and posterior urethral injuries are similar in many cases. Injuries to the female urethra are rare and are repaired acutely.

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Anterior Urethra

The anterior urethra is divided into two segments, the bulbar and the penile urethra. The penile urethra extends from the external meatus to the penoscrotal junction. The bulbar urethra is located just proximal, between the inferior margin of the urogenital diaphragm and the penoscrotal junction.

Blunt trauma typically affects the bulbar urethra as a result of a straddle injury from a fall, crush, or motor vehicle collision [1]. The bulbar area is susceptible to injury because of its fixed position beneath the inferior pubis [2], where it may be crushed against the inferior pubic ramus. Crush injuries of the penile urethra are uncommon; however, laceration of the tunica albuginea of the penis may extend into the penile urethra in 16–20 % of penile fracture injuries [3, 4].

Penetrating urethral injuries may occur because of gunshot wounds or stab injuries to the penis, buttock, abdomen, or scrotum. Iatrogenic anterior urethral injury is associated with traumatic endoscopic procedures or catheter placement. Delayed injury may arise from a chronic indwelling urethral catheter, particularly near the meatus, secondary to pressure necrosis, infection, or chemical irritation [5].

Diagnosis

Any blunt or penetrating injury to the perineum, genitalia, or pelvis should suggest the possibility of urethral injury, and severity can be suggested by

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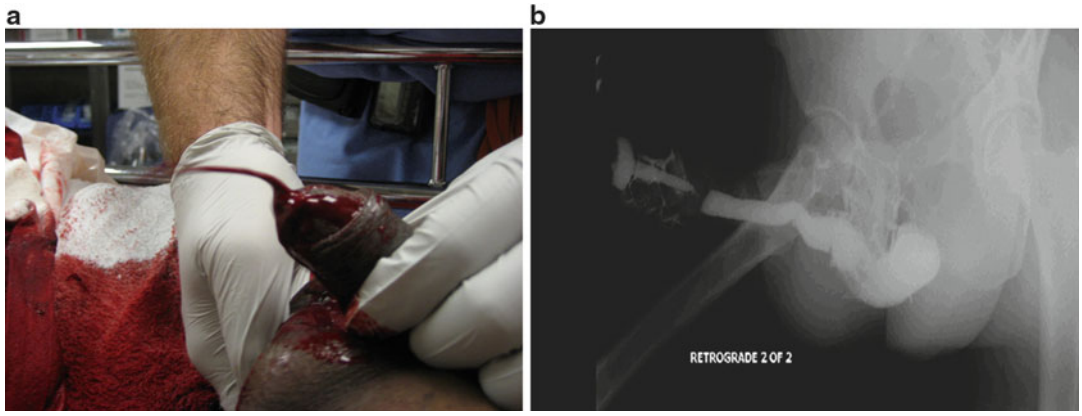

Fig. 6.1 (**a**) Blood from urethra after a worker fell astride a pipe from a height of 2 m. (**b**) Retrograde urethrogram shows contrast extravasation from injury in the bulbar urethra

information about the type of weapon used or the object or force that struck the perineum. A complete voiding history should be obtained, including ability to void spontaneously, time of last void, hematuria, dysuria, and caliber of stream.

The pattern of hematoma and ecchymosis may aid in determining which anatomic spaces are disrupted by an injury [6]. If Buck's fascia is ruptured, blood and urine can extravasate around Colles' fascia, giving a characteristic "butterfly" sign in the perineum [7]. A sleeve distribution limited to the penile shaft indicates that the injury is confined within Buck's fascia.

The finding of blood at the urethral meatus after injury warrants immediate retrograde urethrogram prior to transurethral catheterization (Fig. 6.1). Retrograde urethrography should be performed with contrast injected during film exposure in order to distend the urethra and improve anatomic visualization [8]. Fluoroscopy allows real-time evaluation and immediate appraisal of image quality. If the patient's injuries allow, urethrography should be performed with the penis on stretch and the patient in the oblique position. Contrast may be injected using a Foley catheter, inserted far enough (2–3 cm) for the balloon to be lodged within the fossa navicularis and inflated with 1–2 mL of fluid. Complete visualization of the anterior urethra without extravasation excludes urethral laceration or disruption. Extravasation of contrast is diagnostic of urethral injury; visualization of the entire anterior urethra with an area of extravasation indicates partial disruption, while extravasation with the urethra proximal to this level unfilled with contrast is likely a complete disruption. In men with intact external urinary sphincter tone, contrast may not flow more proximally into the bladder.

Initial Management

The goal of initial management is to provide urinary drainage and minimize potential complications, such as stricture, fistula, and infection. Typically, if the patient is unstable, it is not as a result of urethral injury, so resuscitation is primarily directed at associated injuries to other organs. Moreover, urologic care should be rendered efficiently and effectively in the setting of multisystem trauma; it should not interfere with ongoing treatment of other injuries.

Partial disruptions contained within Buck's fascia can often be managed with transurethral catheterization alone [9]. A Coude catheter or flexible cystoscope is often useful to bypass the injured area safely. Successful healing with a catheter alone is dependent on the preservation of a partially intact mucosa.

Blunt anterior urethral injuries associated with extensive soft tissue damage make evaluation of the extent of injury difficult. Even if urethral continuity is partially maintained, suprapubic catheter diversion is warranted as the risk of dense stricture formation is high [10]. Open debridement

of the urethra and corpus spongiosum is not advised after blunt injury because bruised, otherwise viable erectile tissue may recover even though it can appear ischemic acutely. Overzealous debridement may result in large wounds that require major delayed reconstruction [11]. Significant urethral injury associated with scarring of corpus spongiosum usually results in significant stricture that requires delayed formal urethral reconstruction [12]. Broad-spectrum antibiotics are indicated in patients with extensive extravasation of blood or urine, and suprapubic catheter diversion is advisable, even if a urethral catheter can be placed.

Suprapubic cystostomy is a practical, simple solution for acute management of major injuries. It avoids urethral manipulation and removes the risk of the patient developing acute urinary retention after urethral catheter removal. This is particularly important in crush injuries, such as severe straddle injuries, where a stricture may develop in the weeks following the injury. Suprapubic catheterization is important because it facilitates a period of "urethral rest" where the phases of wound stabilization progress without the continued trauma of an indwelling urethral catheter or repeated instrumentation [13].

Percutaneous placement of a suprapubic catheter is efficient and can be completed in the emergency department; transabdominal sonography can be used to guide the catheter's placement. We prefer to use a 16 Fr Foley catheter inserted via a peel-away sheath system. Open cystostomy may be preferable if the bladder is not palpable suprapubically or the patient is going to the operating room immediately. When suprapubic cystotomy is used as the primary treatment option, the cystotomy tube is maintained for approximately 4 weeks to allow urethral healing. It is then clamped, and voiding cystourethrography is performed. Once normal voiding is confirmed and stable, the tube can be safely removed [2]. When in doubt, a trial of voiding for 1–2 weeks with the suprapubic catheter capped is a prudent option.

Urethral injuries occurring in the context of penile fracture or penetrating trauma are best managed with primary surgical repair. Injuries in the bulbar urethra are usually easily treated by mobilization of the surrounding corpus spongiosum. The authors prefer repair over a 16Fr. catheter with fine, monofilament suture, such as 5-0 PDS. The edges of the urethra should be spatulated to avoid contraction of a concentric scar. The catheter should be left in place for 3 weeks and a voiding urethrogram done at time of removal (Fig. 6.2). Again, debridement of urethral mucosa and the corpus spongiosum should be done sparingly.

Primary repair is probably not justified for transections of the urethra following high-velocity penetrating trauma, such as by military or high-powered rifles, as the energy imparted to the surrounding tissue by the high-velocity missile may cause extensive damage to surrounding tissue that is not immediately apparent. Similarly, primary repair may not be best for extensive injuries to the penile urethra that would require heroic mobilization of the surrounding pendulous urethra, potentially leading to penile curvature. Delicate surgery, such as tissue grafting or flaps, should not be performed in the acute setting. Treatment should be suprapubic diversion, local wound care, and delayed urethral reconstruction.

Delayed Reconstruction

Stricture formation after trauma to the anterior urethra may present rapidly or years after the injury. Although some men may not appreciate symptoms of a urethral stricture that develop slowly over a period of years, many urethral injuries produce substantial tissue damage which produces unmistakable, immediate obstructive voiding symptoms. Proper treatment depends on accurate imaging. Retrograde urethrography combined with voiding cystourethrography delineates the location and severity of the stricture in most cases (Fig. 6.3). A suprapubic catheter, when present, may be used to aid in imaging of the proximal urethral segment. Occasionally repeat imaging may be required when the first attempt is inadequate; direct communication with the person performing the study is recommended.

Although contrast urethrography is informative and practical, it may not predict the degree of spongiofibrosis and tends to underestimate

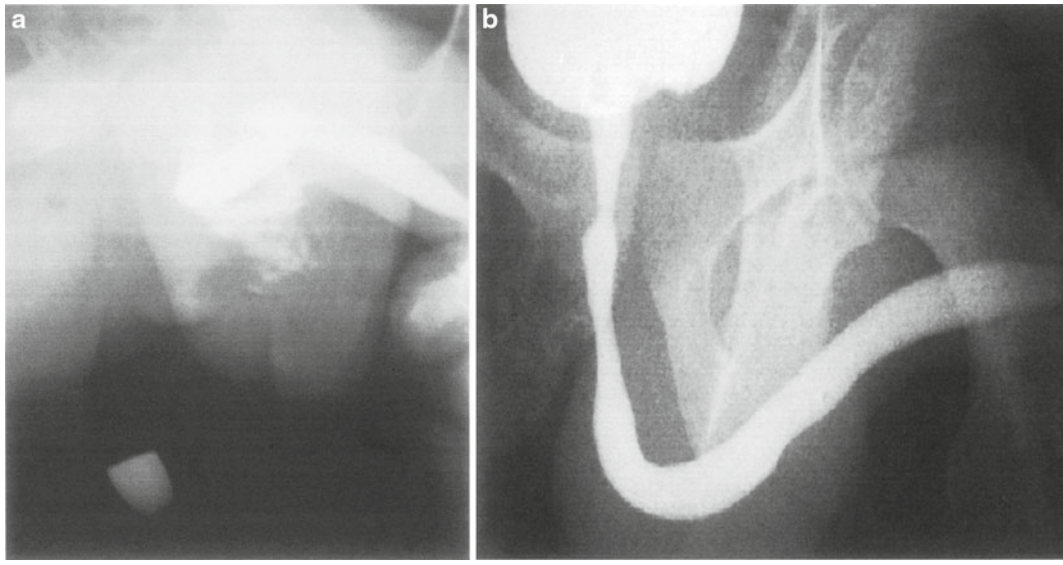

Fig. 6.2 (**a**) Retrograde urethrogram obtained after gunshot wound to buttock demonstrates extravasation from bulbar urethra and bullet retained within scrotum. Primary repair was performed acutely. (**b**) Voiding cystourethrogram 2 weeks after repair reveals completely normal urethra

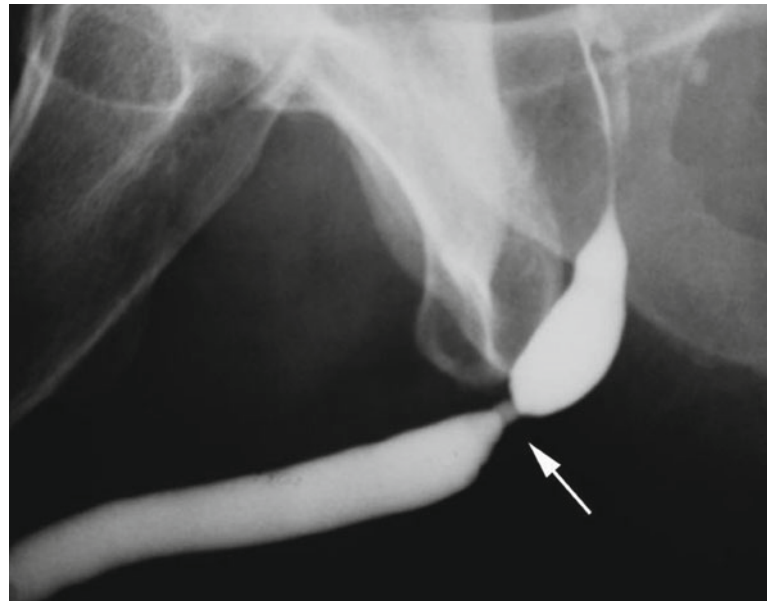

Fig. 6.3 Retrograde urethrogram demonstrates a short but severe stricture after a straddle injury in an all-terrain vehicle collision. Even though this stricture is short, it was surrounded by dense fibrosis and would not have been well treated by internal urethrotomy

stricture length in the bulbar urethra [14]. Sonourethrography is an ancillary staging technique that may complement traditional imaging techniques. Stricture length and diameter may be more precisely measured using ultrasound, resulting occasionally in selection of a different reconstructive procedure than that originally suggested by conventional urethrography [15].

Repair of a traumatic stricture should be delayed enough time to allow the scar to stabilize and most

of the inflammation to resolve, typically at least 2 months after the initial injury [16]. Most traumatic strictures are dense and will recur after dilation or endoscopic urethrotomy. Because of its high failure rate, urethrotomy is best reserved for thin diaphragmatic strictures that arise occasionally after formal repair [17]. Intermittent office dilation or self-dilation is palliative at best and often accomplishes little more than extending the tissue damage and prolonging the patient's misery.

Most traumatic strictures become completely or almost completely obliterated, requiring excision with primary anastomosis (EPA). EPA urethroplasty offers the best opportunity for a stricture-free outcome with long-term cure rates approaching 95 % [18]. Patients best suited for EPA are those who have strictures of the bulbar urethra less than 2.5 cm [19]. For longer bulbar strictures, buccal mucosa graft-augmented anastomotic urethroplasty has been shown to have a stricture-free rate of 93 % [20]. In this technique, the most severe area of stricture is excised, one wall of the urethra is anastomosed directly while the other side is replaced by a buccal mucosal graft. Excessive urethral excision can result in penile shortening or a repair that is under tension and at risk for failure.

Strictures of the penile urethra are rarely amenable to EPA. These strictures tend to be more diffuse than bulbar strictures, and their excision is more likely to produce penile curvature as the ability to mobilize surrounding urethra is not nearly as great as in the bulbar urethra. As a result, substitution procedures involving a graft or flap will be required in most cases [18]. Full-circumference replacement is less successful than an onlay procedure, and aggressive efforts should be employed to preserve or salvage the urethral plate [21].

Posterior Urethra

The posterior urethra consists of the prostatic and membranous urethra. Injuries occur in conjunction with high-energy blunt pelvic trauma and may occur through several mechanisms related to different pattern of pelvic fracture or ligamentous injury [22]. Other causes of posterior urethral injury include perineal or pelvic penetrating trauma, self-instrumentation, and pelvic diastasis without fracture [23]. Long-term complications may include complete urethral occlusion after disruption, partial urethral stenosis, post-injury erectile dysfunction, and occasionally incontinence. Of note, the term "stricture" is typically not used in situations where the urethral continuity is disrupted [24], preferring instead such descriptors as "pelvic fracture urethral disruption defect" or "stenosis."

Injury of the posterior urethra occurs in 10–20 % of all cases of pelvic fractures [25, 26]. Concomitant bladder injury occurs in 18 % of patients with urethral disruptions [27]. These can be severe, life-threatening injuries. Bleeding from fractured bone edges or lacerated blood vessels may cause a large pelvic hematoma. This may elevate and displace the bladder and prostate, stretching an intact urethra or distracting the severed or ruptured urethral ends and causing a gap in urethral continuity. This gap becomes fibrotic as the pelvic hematoma is reabsorbed over time.

Diagnosis

The diagnosis of posterior urethral injury is suggested by a history of pelvic fracture, most commonly following a motor vehicle collision or pedestrian injury, but also after a fall or crush injury. Like anterior urethral injuries, blood at the urethral meatus and inability to void warrant complete urological evaluation. A palpably full bladder or an elevated or indistinct prostate on rectal examination may raise suspicion of urethral injury, but they are insensitive predictors [28].

The pelvis may fracture in several locations and have complex fracture patterns. Fracture patterns associated with urethral injuries most often involve the anterior pubic rami (especially displaced fractures), complex fractures of both the anterior and posterior pelvic arch, and even diastasis of the pubic symphysis without fracture (Fig. 6.4) [26, 29]. Others have found the mechanism

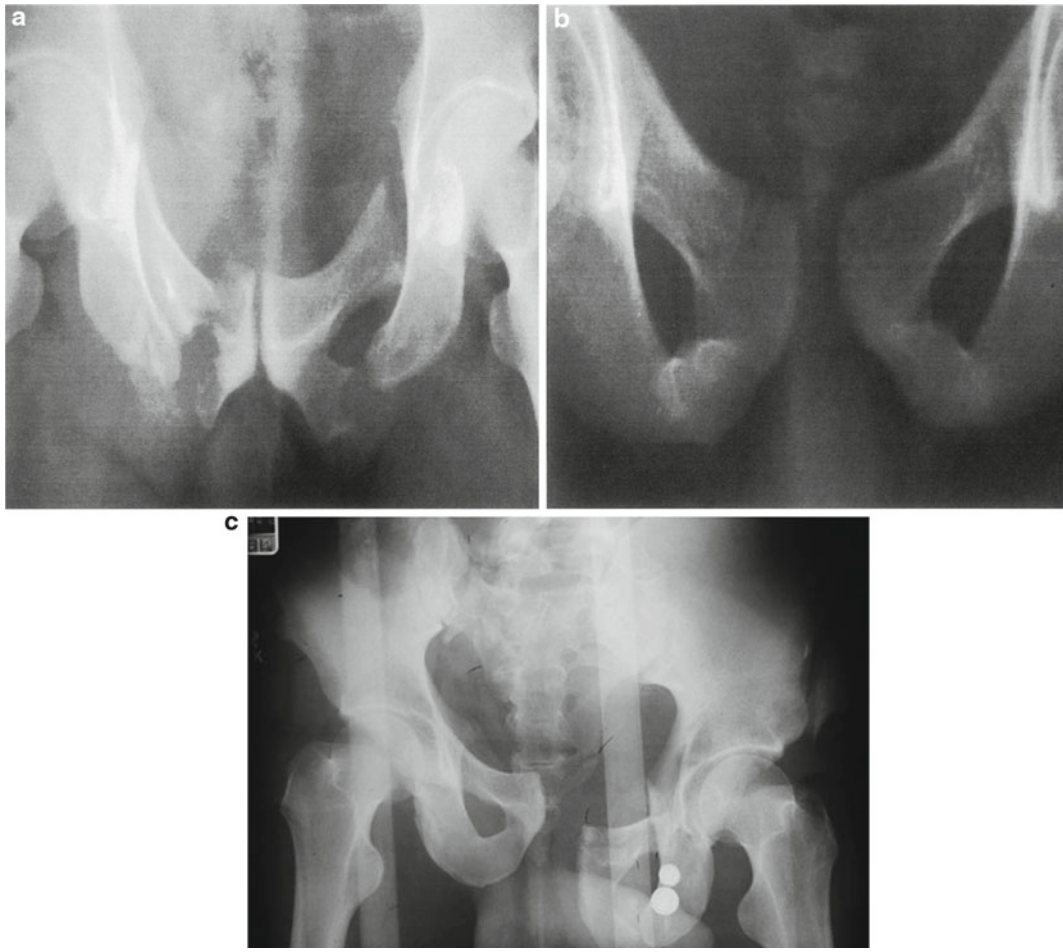

Fig. 6.4 Posterior urethral distraction injuries may occur in conjunction with a variety of pelvic fractures. (**a**) "Straddle" fracture involving bilateral superior and inferior pubic rami, (**b**) barely perceptible pubic diastasis, and (**c**) Malgaigne fracture with vertical displacement are examples of the spectrum of pubic injuries that may be implicated

of injury to be more predictive of urethral injury than specific fracture patterns [22]. These differences illustrate the need for a high level of suspicion in all patients with significant blunt pelvic trauma.

Retrograde urethrogram should always be performed prior to transurethral catheterization when urethral injury is suspected (Fig. 6.5). These patients are often unable to be positioned obliquely, however. A simplified radiologic classification of posterior urethral injuries was proposed by a World Health Organization panel of experts [24]:

1. Posterior urethral stretched but intact
2. Partial disruption
3. Complete disruption
4. Complex injury (involves bladder neck/rectum)

Computed tomography is commonly used in diagnosis of the trauma patient and is frequently performed prior to suspicion or confirmation of a urethral injury. Sometimes the patient may have had an attempt at urethral catheterization prior to urethral evaluation. CT findings highly associated with urethral injury include obscuring of the urogenital diaphragm fat plane, the prostatic contour, or bulbocavernosus muscle, as well as hematoma of the ischiocavernosus

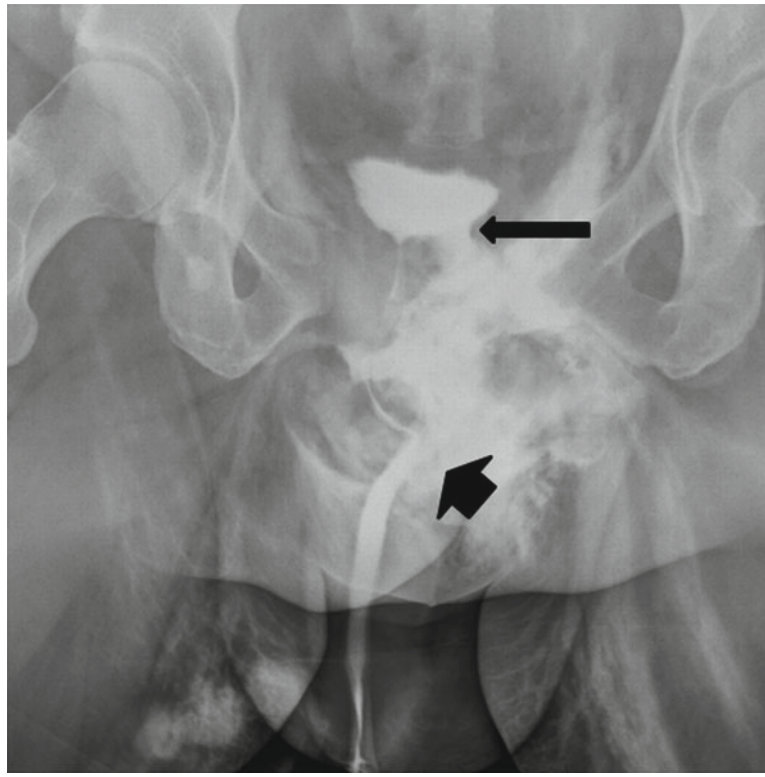

Fig. 6.5 Retrograde urethrogram shows extravasation from partial urethral injury (*short arrow*) and partial bladder filling after motor vehicle collision and pelvic fracture. Additional extravasation from extraperitoneal bladder injury (*long arrow*), confirmed at open exploration

muscle or obturator internus muscle [30]. In cases of partial urethral disruption, a blind catheterization may at times be successful prior to recognition of urethral injury, allowing for the diagnosis of a urethral injury at time of CT cystography. While magnetic resonance imaging (MRI) may be useful in planning delayed reconstruction, it has little role in the acute setting. Urethral ultrasound has no role in the diagnosis of posterior urethral injuries.

Initial Management

Initial management depends on the patient's hemodynamic stability and the status of associated orthopedic and non-orthopedic injuries. Coordination among the trauma surgeon, the orthopedist, and the urologist is critical. Two options exist for the management of posterior urethral injury: suprapubic cystostomy with delayed repair or primary urethral realignment. In the past, immediate open repair with pelvic hematoma evacuation was suggested [31]. Immediate sutured repair is not recommended because it is associated with unacceptably high rates of erectile dysfunction and incontinence [32]. Associated injuries of the bladder neck, vagina, or rectum necessitate immediate repair.

Suprapubic cystostomy alone avoids the risk of disrupting or infecting the pelvic hematoma and expedites treatment in the severely injured patient. Suprapubic cystostomy is especially advantageous when the patient is critically unstable or when realignment cannot easily be performed [32].

Primary realignment implies stenting the damaged area with a transurethral catheter. The goal is to allow a partial urethral injury to heal with a catheter in place or to align both ends of the

disrupted urethra so that they heal in the correct position as the pelvic hematoma is reabsorbed. The catheter is *not* placed on traction, and it is removed 4–6 weeks later when there is no contrast extravasation seen on retrograde or voiding urethrography [33]. Although realignment procedures have been performed either immediately or subacutely, several days after the initial injury when the patient is stable, most are doomed to failure. For this reason, a suprapubic tube should be maintained in most cases to provide immediate urinary diversion in the event that the patient goes into urinary retention. Bladder neck injuries should be repaired via open surgery during the initial presentation to prevent loss of the bladder neck's continence mechanism [34].

Manipulation of delicate and injured tissues during prolonged endoscopic realignment procedures risk infecting the pelvic hematoma or potentially damaging future continence or erectile function, and should therefore be avoided. A variety of techniques, including retrograde passage of a catheter through cystotomy under direct vision and endoscopically assisted catheter realignment have been described for realignment [23, 35]. Suprapubic cystostomy enables antegrade access to the urethra. The authors firmly believe a suprapubic catheter should be placed even if urethral realignment is successful because most patients will develop some degree of stenosis once the urethral catheter is removed (Fig. 6.6) [23]. Although orthopedic surgeons may understandably express concern that a suprapubic cystostomy tube may increase the risk of infection of hardware used for internal fixation of anterior pelvic fractures, there is little published data available for guidance. In the authors' experience, directing the catheter up away from the injured pubis is associated with a very low risk of hardware infection.

Retrospective reports indicate that some urethral injuries may heal without stenosis and may not require open reconstruction [33, 35]. Although the authors have rarely observed this phenomenon, this represents an area of controversy among reconstructive experts. One argument in favor of primary realignment is that patients who develop stenosis may have a technically easier reconstruction due to the disrupted ends of the urethra being in closer proximity than in cases where alignment had not been performed [36]. Proponents suggest that stenosis after realignment may often be treated with internal urethrotomy. However, recurrent stenosis after endoscopic treatment occurs in over 80 % of patients, and repeat endoscopic treatments are even more likely to fail [37]. We have observed considerable delays and complications arising as a result of failed realignment procedures in young men who ultimately were salvaged by open urethroplasty.

Rates of erectile dysfunction and incontinence with primary realignment have been comparable to those achieved by delayed repair [23, 25]. Over 50 % of patients who have a pelvic fracture urethral disruption injury will report some degree of erectile dysfunction [38]; historical rates of incontinence for both methods are <5 % [32]. Most authorities now believe that impotence and incontinence result from the initial injury, not secondary to surgical management [39]. Delayed return of potency is not uncommon, occurring as late as 3 years after injury [40].

Delayed Reconstruction

Posterior urethroplasty will be necessary in patients who have a significant urethral continuity defect after pelvic injury. This includes almost all patients treated with suprapubic cystostomy alone at the time of injury. Some patients who have undergone primary realignment may not need open surgical reconstruction, but those who develop significant stenosis may need formal urethroplasty. Patients having undergone realignment procedures should have follow-up urethroscopy and/or urethrography to ensure urethral patency.

As the pelvic hematoma is reabsorbed, the gap between the prostatic apex and the distal edge of the urethra is reduced, typically leaving a 1- to 2-cm gap of fibrosis. Complete excision of the scar and direct urethral anastomosis (Fig. 6.7) is performed when the patient has recovered from major associated injuries, usually after about 3 months [41].

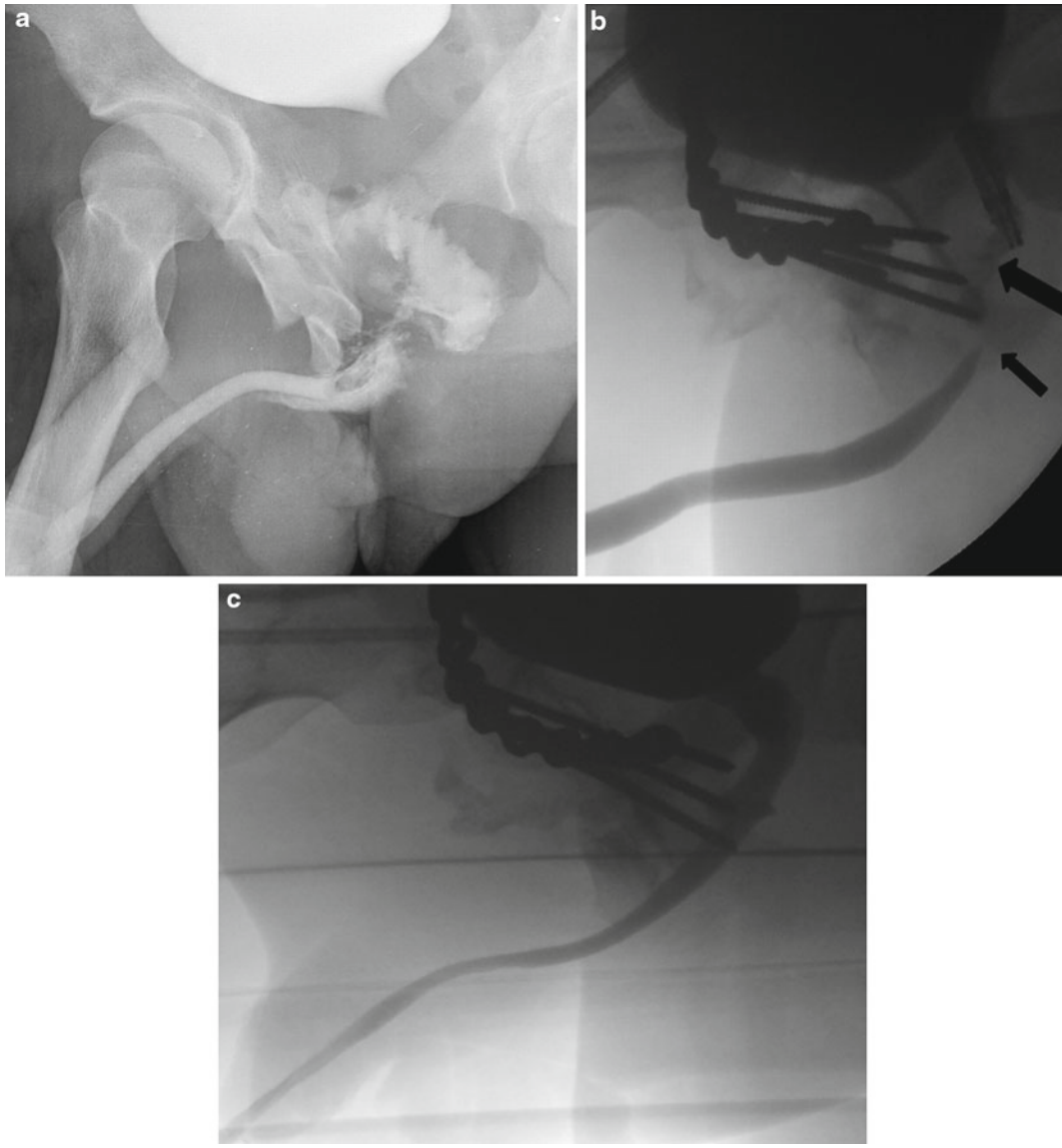

Fig. 6.6 (**a**) Retrograde urethrogram shows complete urethral disruption after pelvic crush injury. Contrast in bladder is from prior intravenous contrast for abdominal CT scan. Note that the bladder is elevated out of the pelvis. (**b**) Patient underwent primary urethral realignment at time of internal fixation repair of pelvic fracture. Stenosis developed (*small arrow*) after urethral catheter removal. Note stone fragments (*large arrow*), formed during prolonged catheterization, in urethra above level of stenosis and distal to antegrade urethroscope. (**c**) Voiding urethrogram after successful posterior urethroplasty

Retrograde urethrography with simultaneous cystography helps to determine the length of the defect and competency of the bladder neck. Alternatively, flexible antegrade cystoscopy may be combined with retrograde urethrography when the patient is unable to pass contrast below the bladder neck. MRI [42] or CT cystourethrography [43] can provide additional information in selected complex or reoperative cases.

Complete resection of the fibrotic segment with end-to-end anastomosis is the most successful method for posterior urethral reconstruction [44]. Mobilization of the bulbar urethra distally to the penoscrotal junction takes advantage of the

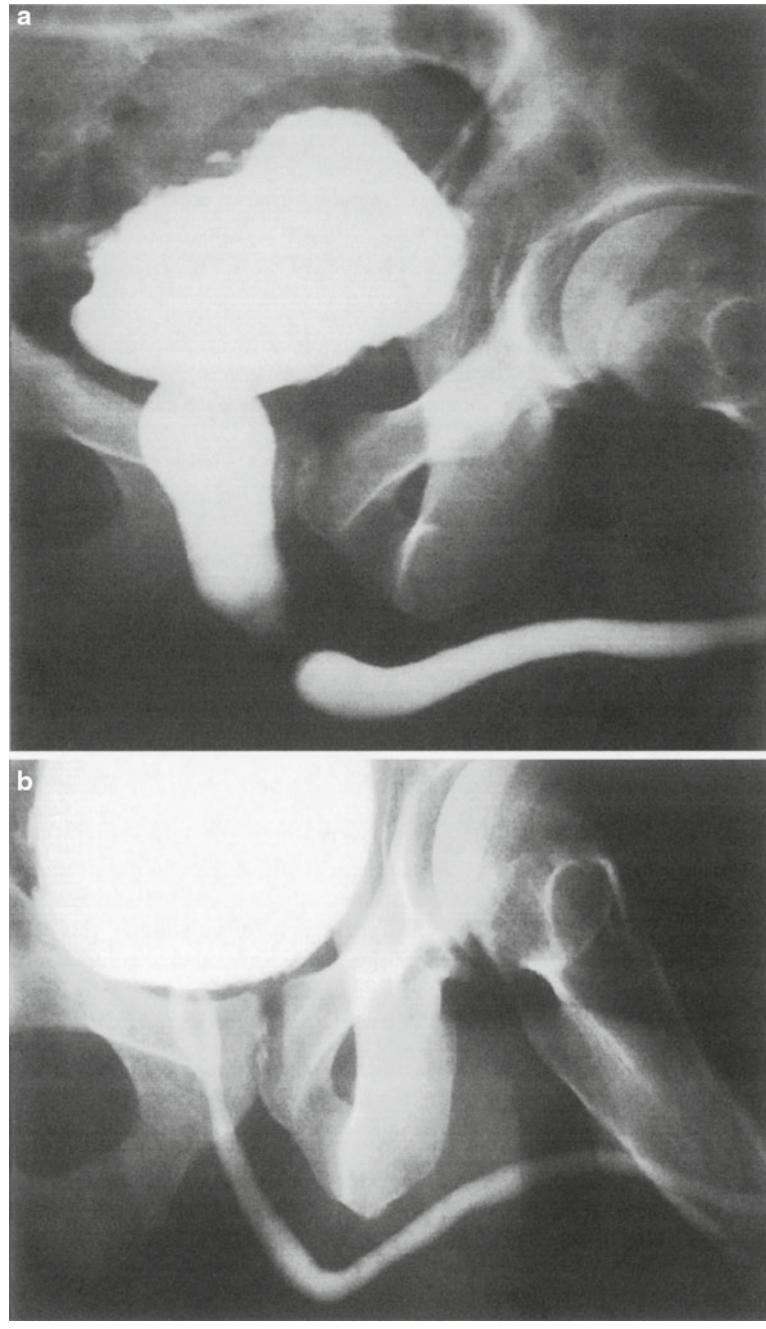

Fig. 6.7 (**a**) Combined retrograde urethrography/voiding cystourethrogram reveals urethral gap 3 months after posterior urethral disruption. (**b**) Postoperative voiding cystourethrogram after successful posterior urethral reconstruction via excision/primary anastomosis technique reveals normal urethral lumen

elasticity of the bulbar urethra to make up most urethral defects. If necessary, corporal body separation, inferior pubectomy or supracrural urethral rerouting may be utilized in sequential fashion to bridge the defect [45], although the authors have found these steps to be unnecessary nearly always, time-consuming, and occasionally harmful [46]. Although a perineal approach is

adequate in most cases, transpubic procedures are appropriate for complex or reoperative cases in which a tension-free bulbo-membranous anastomosis is not otherwise possible [47, 48]. Unlike anterior urethral reconstruction, tissue grafts and flaps are rarely indicated.

Posterior urethroplasty is highly successful having over 85–90 % long-term stricture-free success without additional intervention, in experienced hands [37, 49]. Incontinence is uncommon after posterior urethroplasty, and erectile dysfunction as a result of urethroplasty itself is rare [37]. Because most disruptions occur at the bulbo-membranous junction [50], some external sphincter function may remain intact. In others, continence after posterior urethral reconstruction relies on the bladder neck and prostate. An open bladder neck on a preoperative cystogram, however, does not prove functional incompetence [51, 52]. Understanding the contribution of the bladder neck to urinary continence is important in these patients; future prostate surgery may compromise this function.

Summary

Urethral injury may be of secondary importance at the time of presentation of the acute trauma victim. However, devastating urological complications such as sexual dysfunction, incontinence, and urethral stenosis or stricture may drastically impair quality of life, often long after other injuries are healed. A high index of suspicion is necessary to ensure early, accurate diagnosis and prompt, effective treatment of urethral injuries.

Urethral injury should be considered in the setting of penile fracture, pelvic fracture, or penetrating trauma to the genitalia, pelvis, or perineum. Blood at the meatus always indicates the need for retrograde urethrogram or flexible cystoscopy in the trauma setting.

Immediate repair is usually possible in urethral injuries associated with penile fracture or penetrating injuries to the anterior urethra. For pelvic fracture urethral injuries, suprapubic cystostomy with delayed reconstruction is a safe, proven strategy, although primary realignment with catheter placement is reasonable when it is possible without heroic measures. Continence and potency rates seem to be associated more with the nature of the injury than with the method of urological management.

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Trauma to the External Genitalia

7

Alex J. Vanni

Introduction

Traumatic injuries to the external genitalia are rarely fatal, but can have profound morbidity that permanently impairs quality of life. In order to minimize both the short- and long-term devastating complications associated with these injuries, prompt evaluation, diagnosis, and management are essential. Although trauma to the external genitalia is uncommon, early intervention coupled with systematic treatment strategies serves to minimize the complications of bleeding, infection, and organ injury while optimizing fertility, sexual health, micturition, cosmesis, and psychological well-being.

Men suffer trauma to the external genitalia at a higher incidence than women both as a result of anatomic exposure and an increased propensity for the most common risk factors for genital trauma. Men are more likely to be involved in violence involving both blunt and penetrating injuries, motor vehicle collisions, and to participate in aggressive sports [1, 2]. In addition to the common causes of genital trauma, urologists must be knowledgeable about the diverse mechanisms of injury including lacerations/avulsion injuries, self-mutilation, burns, bites, female genital mutilation, and sexual assault. The American Association for the Surgery of Trauma (AAST) Organ Injury Scale [3] is a graded scoring system used to classify blunt and penetrating injuries to the external genitalia (Tables 7.1 and 7.2). The AAST Organ Injury Scale systematically categorizes genital injuries and has been shown to be a useful predictor for surgical intervention in traumatic injuries to the external genitalia [4]. Thus, careful examination, diagnosis, and treatment of these injuries will optimize the likelihood of a successful outcome.

Pathophysiology of Trauma to the Scrotum and Testicles

Blunt Scrotal Trauma

Blunt trauma to the scrotum can result in a variety of injuries including an intrascrotal hematoma, testicular dislocation, testicular rupture, and hematocele (Table 7.1). Testicular trauma occurs predominately in men ages 15–40 [5]. Blunt trauma to the scrotum remains the most common mechanism of traumatic testicular injury, resulting in 85 % of injuries [6]. The vast majority of these injuries are a result of assault, motor vehicle collisions, a variety of sporting events, bicycle and horseback riding, as well as other straddle injuries [7]. Bilateral testicular injury only occurs in about 1 % of patients presenting with scrotal trauma [8].

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Table 7.1 American Association for the Surgery of Trauma (AAST) organ injury scales for male genitalia

Injured structure	AAST grade	Characteristics of injury
Scrotum	I	Contusion
	II	Laceration <25 % of scrotal diameter
	III	Laceration ≥25 % of scrotal diameter
	IV	Avulsion <50 %
	V	Avulsion ≥50 %
Testis[a]	I	Contusion or hematoma
	II	Subclinical laceration of tunica albuginea
	III	Laceration of tunica albuginea with <50 % parenchymal loss
	IV	Major laceration of tunica albuginea with ≥50 % parenchymal loss
	V	Total testicular destruction or avulsion
Penis[b]	I	Cutaneous laceration or contusion
	II	Laceration of Buck's fascia (cavernosum) without tissue loss
	III	Cutaneous avulsion, laceration through glans or meatus, or cavernosal or urethral defect <2 cm
	IV	Partial penectomy or cavernosal or urethral defect ≥2 cm
	V	Total penectomy

[a]Advance one grade for bilateral injuries, up to grade III
[b]Advance one grade for multiple injuries, up to grade III

Table 7.2 AAST organ injury scale for female external genitalia

Injured structure	AAST grade	Characteristics of injury
Vulva	I	Contusion or hematoma
	II	Superficial laceration (skin only)
	III	Deep laceration (into fat or muscle)
	IV	Avulsion (skin, fat, or muscle)
	V	Injury to adjacent organs (anus, rectum, urethra, bladder)

Testicular Dislocation

Testicular dislocation is a rare traumatic event that results in the testicle being displaced from its normal anatomic position in the scrotum [9]. While the spermatic cord remains intact in the vast majority of cases, testicular torsion and avulsion are possible due to the substantial force involved in these injuries [9]. Dislocation is most commonly a result of a straddle injury related to a motorcycle crash, but can also occur in motor vehicle collisions and car vs. pedestrian accidents. Dislocation is most commonly unilateral, but has been reported to be bilateral as high as 25 % in one series [10]. Sites of testicular dislocation include the inguinal canal, pubic, penile, and abdominal cavity, perineal, acetabular, femoral canal, and crural areas [11]. Patients usually present with considerable pain. A massive scrotal hematoma may limit an effective physical exam, which, if possible, will reveal an empty hemiscrotum. Significant blunt force is required to dislocate the testicle. Therefore, it is imperative to rule out secondary injuries to the testicle such as torsion, rupture, and intratesticular hematoma.

Testicular Rupture

The testicle is protected from injury by both the mobility and elasticity of the scrotum and the durability of the tunica albuginea. The tunica albuginea of the testis provides substantial protection, with an ability to endure forces of up to 50 kg before rupturing [12, 13]. Blunt testicular rupture results from compression of the testis against the pubic arch, symphysis, or thigh with subsequent extrusion of seminiferous tubules. Rupture of the tunica albuginea may result in

simple longitudinal or transverse tears or may be more complex with either a stellate tear or complete destruction of the testicle. Regardless of the mechanism of injury, testicular rupture warrants immediate evaluation and surgical treatment to maximize testicular salvage [7, 14].

Hematocele

Blunt trauma to the scrotum can result in blood accumulating between the visceral and parietal layers of the tunica vaginalis resulting in a hematocele. Rupture of the parietal tunica vaginalis will result in fluid extending into the perineum and groin, often with dissection into the subcutaneous dartos. Importantly, this blood can result from a rupture of the tunica albuginea causing blood from within the testicle to accumulate outside the testis. Testicular exam is usually difficult with moderate to large hematoceles, as both the fluid around the testicle and patient discomfort limit an accurate examination. When scrotal ecchymosis occurs in this clinical scenario, it is impossible to ascertain the degree of injury on physical examination alone. Color duplex Doppler ultrasonography can assess the integrity of the tunica albuginea, blood flow to the testicles, and size of hematocele [5, 7, 14, 15].

Intrascrotal Hematoma

Blunt trauma to the scrotum frequently results in intrascrotal bleeding. The distinct anatomical location and configuration of the scrotum lend itself to the accumulation of large amounts of blood and edema. Minor bleeding can evolve into a major hematoma if not treated quickly as the elasticity of the scrotum can accommodate large volumes of blood before tamponading. Significant hematomas left untreated can result in considerable pain, infection, as well as testicular atrophy and infarction [7].

Vulvar Trauma

Blunt injury to the female external genitalia is more likely to result in injury to nearby associated organs, including the vagina, urethra, bladder, and rectum. Blunt injuries to the female genitalia must be regarded with particular care because of their association with sexual assault and other interpersonal violence. Sexual assault victims suffer genital trauma in 20–53 % cases [16, 17]. Blunt trauma resulting from motor vehicle collisions, including pelvic fracture, or straddle injuries may result in vulvar hematomas and lacerations, as well as perineal and vaginal injuries (Table 7.2) [18–20]. The management of the more complex picture of concomitant genital and bladder injuries is covered in greater depth in Chaps. 5 and 6.

Penetrating Scrotal Trauma

Gunshot Wound

Penetrating trauma to the scrotum and testicles is significantly less common than blunt injuries. The majority of such injuries are the result of gunshot wounds (Fig. 7.1) [1, 21]. Approximately 21–55 % of genitourinary gunshot wounds result in scrotal injury, while 12–39 % result in an injury to the testicles [1, 22]. Despite the relatively infrequent nature of penetrating injuries to the scrotum, gunshot wounds result in bilateral testicular injury at 15 times the rate as in blunt injury, with bilateral testicular injuries accounting for 6–30 % of penetrating scrotal injuries [1, 21, 23, 24].

The degree of injury to the scrotum and testicles is related to the caliber of gun and the velocity of the missile. Most hand guns range from 0.22 to 0.45 caliber and have low-velocity missiles that travel at 1,000 ft per second. These low-velocity missiles typically have minimal damage outside the path of the projectile. In contrast, high-velocity missiles travel at greater than 1,000 ft per second and result in significant tissue damage by the explosive effect of the missile upon impact. Consequently, these weapons often result in life-threatening injuries as the projectile damages tissue radially along its path [25]. Shotguns are considered low-velocity weapons; however, the high mass of its projectiles often results in significantly more damage than occurs with a single low-velocity gunshot.

Civilian and battlefield penetrating injuries vary dramatically due to the differences in weapons

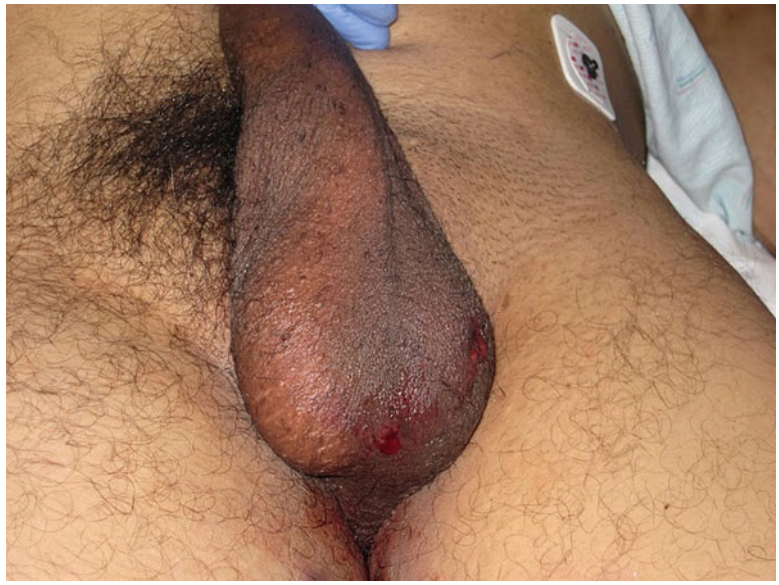

Fig. 7.1 Gunshot wound to the scrotum with a low-velocity projectile

being used. Historically, military genitourinary injuries involved the use of high-velocity guns. Increasingly, a changing pattern of warfare has led to the implementation of high-velocity fragmentation devices that have resulted in significant pelvic and genital organ injuries. In Operation Iraqi Freedom, 68 % of all patients with a genitourinary injury had one or more injuries to the external genitalia despite the use of protective armor [26, 27].

Any patient with a gunshot wound to the external genitalia should be evaluated with a high index of suspicion for other associated injuries. The reported rate of associated injuries with penetrating scrotal trauma varies by institution, but ranges from 50 to 94 % [2, 28]. Although the mortality rate for an isolated gunshot wound to the genitalia is rare, appropriate consultation with trauma surgeons is imperative to properly manage associated injuries.

Self-Mutilation, Stab Wounds, and Lacerations

Genital self-mutilation usually results in catastrophic testicular injury. A majority of these patients view themselves as male, although a number identify themselves in an alternate nonmale, nonfemale space [29]. Guilt associated with sexual conflicts has been shown to be the most common feeling in the act of psychotic autocastration, although a variety of etiologies for self-mutilation exist [30]. Most men are actively psychotic at the time of self-mutilation, and frequently under the influence of drugs or alcohol [22, 31, 32]. Among nonpsychotic mutilators, disorders of sexual identity, fanatical religious beliefs, other character disorders, and transvestitism can all serve as motivation for autocastation [30, 32]. The testicular salvage rate of men who attempt autocastration is poor, with only 23 % of testicles salvaged in one large Level I trauma center [22].

Stab wounds or lacerations to the scrotum that are not self-inflicted can also lead to devastating injuries to the testicles and spermatic cord. Phonsombat et al. found that only 23 % of testicular injuries secondary to stab wound were a result of a stab wound that was not self-inflicted. While these injuries are less common than self-inflicted wounds, they result in equally disappointing testicular salvage rates, with only 24 % of testicles able to be saved [22]. The poor testicular salvage rate in stab wounds to the scrotum suggests that the spermatic cord is irreparably damaged during the traumatic event, rendering the testicle unsalvageable.

Scrotal Bites

Mammalian bites rarely occur, but are most frequently caused by a canine attack. Approximately 1 % of all emergency department visits in the United States are a result of animal bites, with 60–70 % occurring in children [33–36]. Despite the large number of animal bites, few affect the genitalia [37, 38]. Bites to the scrotum can result in genital skin loss, infection, and injury to the testicle and spermatic cord. One of the most devastating complications, infection, can occur in up to 30 % of uncomplicated wounds, although this can usually be averted with prompt surgical care [39, 40]. The most common infectious organism associated with dog and cat bites is *Pasteurella*. However, animal bites are often polymicrobial in nature involving *Staphylococcus aureus*, *Streptococcus pyogenes*, and anaerobes [41, 42]. Among the most devastating infectious complication associated with animal bites is rabies. Approximately 55,000 people died worldwide in 2004 from Rabies infections. Human bites pose additional infectious risks to the patient. In addition to a higher rate of bacterial infection, human bites pose the risk of human immunodeficiency virus, hepatitis B and C, herpes simplex virus, tetanus, tuberculosis, actinomycosis, and toxic shock syndrome [42, 43].

Scrotal Avulsion

Avulsion injuries to the scrotum can result from a variety of mechanisms, but most frequently occur as a result of power take off (PTO) machinery accidents, when clothing becomes entrapped in moving parts (scrotum is trapped by stationary object), or in deceleration injuries (bicycles, motorcycles, motor vehicle collisions) [44]. The unique viscoelastic properties of the scrotum usually preclude injury to the testicles, limited instead to the skin and underlying dartos.

Scrotal Burns

Burns to the genitalia rarely occur in isolation and usually are part of a larger total body surface area burn, occurring in 5–13 % of cases [45]. Genital burns can be a result of thermal, chemical, or an electrical etiology. Close attention to children with burns is necessary as child abuse has been found to occur in 46 % of boys and 48 % of girls younger than 2 years old who present with scald burns to the genitalia [46]. While thermal burns are the most common type of external genital burn, it is electrical burns that are the most difficult to treat. Electricity passes through the body from its original point of contact to a point of exit, often damaging deeper tissue layers. The depth of burn is the most important factor in subsequent management and healing. Burns are typically stratified into three categories. First-degree burns affect only the epidermis and are characterized by erythema without blistering. Second-degree burns involve the epidermis and part of the dermis resulting in erythematous, painful lesions. All first- and most second-degree burns will reepithelialize over time. Third-degree burns are the most severe as they are full-thickness burns of the epidermis and entire dermis. These present as painless lesions that are white/brown and firm and require surgical debridement and grafting for successful management.

Initial Evaluation of Scrotal, Testicular, and Vulvar Trauma

Traumatic injury to the scrotum and testicles can be difficult to evaluate due to swelling, bruising, and pain associated with such injuries. A thorough history is important to elucidate potentially more severe injuries than may be initially observed on physical examination. Nausea, vomiting, extreme pain, bruising, or swelling may all suggest more extensive injury. Determining whether the mechanism of injury involved straddle injury, penetrating trauma (type of weapon involved), a bite, or burn is important to identify factors associated with potentially more significant injuries and higher risk of infectious complications.

A complete physical exam of the scrotum or vulva is performed taking note of the integrity of the genital skin and any accompanying hematoma and penetrating, lacerating, or avul-

sion injuries. Additionally, careful evaluation of all the scrotal contents including the testicles, epididymides, and spermatic cords is mandatory. In addition to a careful physical examination, a urinalysis is mandatory in all patients with trauma to the external genitalia. Due to the difficulty in adequately examining the testicles following blunt traumatic injury, high resolution color Doppler ultrasound with a 7.5–12 MHz probe is essential when the physical examination does not clearly demonstrate normal scrotal or testicular findings [14, 15]. Ultrasound is highly sensitive for the majority of blunt injuries that require surgical management, as it is useful in determining the integrity of the testicle and its arterial blood flow. Sonographic examination will allow identification of tunica albuginea tears with a sensitivity of 100 % and specificity of 65 %, diagnosis of hematocele (sensitivity of 87 %, specificity 89 %), testicular hematoma (sensitivity 71 %, specificity 77 %), and testicular avulsion (sensitivity 100 %, specificity 97 %) [14, 15]. In addition, even minor trauma can result in delayed scrotal pain. Ultrasound is useful in this scenario because testicular torsion must be kept in the differential diagnosis. Retrograde urethrogram should be performed in any patient with blunt injuries suggestive of urethral injury. This includes straddle injuries, blood at the meatus, hematuria on urinalysis, or an inability to void.

Penetrating scrotal injuries often involve multiple organ systems and frequently damage the urethra, corpora cavernosa, and spermatic cords. Consequently, these patients may require additional imaging with a CT scan of the abdomen and pelvis with or without cystography, cystourethrography, and proctoscopy to exclude additional injuries. Patients with a concomitant penile injury, blood at the meatus, hematuria on urinalysis, or an inability to void should undergo a retrograde urethrogram to rule out urethral injury [22].

A complete history and physical examination is essential to proper diagnosis and should always include suspicion of sexual assault. If sexual assault is suspected, informed consent must be obtained for the remainder of the patient evaluation, with care being taken to respect the emotional situation of the patient. In addition, the physician should notify the police and appropriate support services that a sexual assault may have occurred, making sure to closely follow all local legal protocols.

It is essential to follow guidelines as outlined by the American College of Obstetrics and Gynecologists for the collection of evidence and laboratory specimens needed for forensic analysis [47]. All female patients with evidence of lower urinary tract trauma should be evaluated for trauma to the external genitalia, including a speculum examination [48]. In cases of suspected sexual assault, this exam should include vaginal swabs or smears for the detection of spermatozoa [49]. Due to both the physical and emotional nature of the traumatic event, examination may need to be performed under anesthesia. Depending on the nature and extent of injuries, other specialists may be required for optimal patient management (pediatrician, gynecologist, trauma surgeon), as complete evaluation of both the vagina and rectum may be necessary to rule out associated injuries.

In blunt trauma of the vulva not related to sexual assault, care must be taken to exclude injuries to the bladder, urethra, vagina, perineum, and rectum. Blunt trauma of the pelvis and straddle injuries can result in perineal and vaginal injuries as well as other gynecologic and gastrointestinal injuries. Blood at the meatus or vaginal introitus implies a vaginal, bladder, or urethra injury. Workup warrants speculum examination and cystourethroscopy and proctoscopy as indicated [50, 51]. Proper imaging with CT or MRI is necessary to exclude pelvic fractures and other intra-abdominal pathology [18, 19, 52].

Penetrating injuries of the female external genitalia are exceedingly rare. Hemodynamically stable patients should be imaged with a CT scan of the abdomen and pelvis to exclude intra-abdominal injury and require complete examination as previously mentioned. Hemodynamically unstable patients should undergo exploratory laparotomy without further workup.

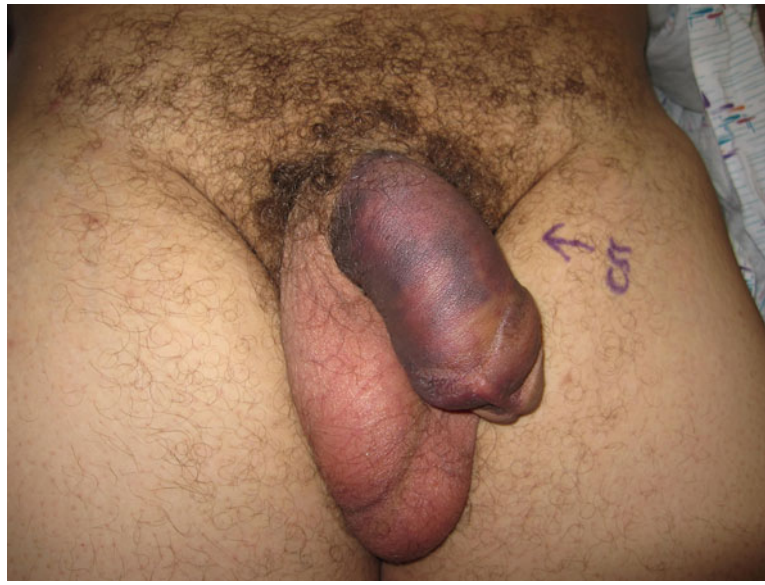

Fig. 7.2 Blunt trauma to the penis resulting in a penile fracture and an "Eggplant Deformity." Hematoma contained by Buck's fascia

Pathophysiology of Traumatic Penile Injury

Blunt Trauma

Penile Fracture

Traumatic injuries to the penis are rare, with variable etiology. Penile fracture is an injury of the tunica albuginea that only occurs with full penile tumescence. To illustrate the rarity of this injury, in the United States, approximately 1,000 people were hospitalized over a 2-year period according to the National Inpatient Sample [53]. The largest series of penile fractures are reported from Northern Africa and the Middle East, suggesting that the incidence of injury is higher in these regions of the world [54–56]. Penile fracture usually occurs in men between the age of 30–40, and most commonly occurs during sexual intercourse, masturbation, rolling over in bed, and kneading the penis to achieve detumescence [54–59]. The etiology of penile fracture is variable, often related to the geographic area of study [56–58]. The majority of cases reported in the western hemisphere result from sexual intercourse, while a larger proportion of fractures in the Middle East result from masturbation [54, 58–60].

Blunt injury to the penis in the flaccid state requires extensive kinetic energy and force because the tunica albuginea is approximately 2 mm thick and can undergo maximal degrees of bending without damage. In the fully erect state, increased rigidity and tumescence of the penis cause the tunica albuginea to thin to approximately 0.25 mm [61]. A penile fracture occurs when the sudden rise in intracorporeal pressure associated with bending compromises the integrity of the tunica albuginea and results in a tunical tear [57, 62]. During intercourse this most frequently occurs as the erect penis slips out of the vagina and strikes against the pubic bone or perineum. The resulting pattern of hematoma corresponds to the tissue injured in the fracture. If the patient presents with the classic "eggplant deformity," the hematoma is confined to Buck's fascia (Fig. 7.2), whereas if Buck's fascia is disrupted, the hematoma can spread to the scrotum and perineum.

Tears of the tunica albuginea are usually unilateral and transverse; however, bilateral ruptures can occur in 5–14 % of cases [55, 59].

Longitudinal tears in the tunica have been reported, but are thought to result as an extension of a transverse rupture [63, 64]. Rupture of the tunica occurs proximally in 25–57 % of cases, whereas it occurs distally in only 6–26 % of cases [54, 55]. Fractures that occur during intercourse typically present ventrally along the shaft of the penis [65]. Penile fracture predominately affects the tunica albuginea, although it has been associated with lacerations of the corpus spongiosum and urethra in 6–22 % of cases [55, 59, 66]. The mechanism of urethral injuries has not been well studied, but generally reflect extensions of a ventral tear across the midline to involve the corpus spongiosum. Urethral injury rarely occurs (1.6 %) when the fracture has a noncoital etiology [54]. In contrast, coital-related penile fractures have urethral injury rates as high as 58–95 % in some series [56, 65–67].

Rupture of the suspensory ligament, dorsal vein, and/or artery can mimic penile fracture and has been reported to occur in up to 12 % of cases suspected of being a penile fracture [59, 68, 69]. This mimicry is a result of a similarly sounding "popping" sound that often occurs with these injuries, although the lack of detumescence should alert the physician to this diagnosis [70].

Penetrating Trauma

Gunshot Wound

Penile gunshot wounds are rare events due to the anatomic location, size, and mobility of the penis. However, these injuries are complex and potentially devastating for the patient. The largest reported series historically are from the military during the Vietnam War era, where 18.5 % of genitourinary injuries affected the penis [71]. Modern warfare has evolved dramatically with the use of improved body armor. Despite the changing patterns of weaponry and armor, a similar rate (6 %) of genitourinary injuries affecting the penis was seen in Operation Iraqi Freedom [27]. Civilian data is limited to large single institution series. Civilians with gunshot wounds to the penis have associated injuries in 80–90 % cases, most commonly in the thigh (69–75 %) and scrotum (52–56 %) [22, 72, 73]. As previously discussed, the degree of tissue destruction is highly dependent on the caliber of weapon and velocity of missile. Careful attention must be given to exclude a concomitant urethral injury, as 6–24 % of civilians with a gunshot wound to the penis sustain a urethral injury [22, 72, 73].

Self-Mutilation, Stab Wounds, and Lacerations

Penile stab wounds occur as a result of assault or are self-inflicted. There is a paucity of literature on stab wounds of the penis, with reports being limited to case reports and small series. The proportion of penile stab wounds and lacerations varies by institution, ranging from 10 to 18 % of traumatic genital injuries in large Level I trauma centers [22, 74]. In addition to a potential laceration or amputation of the penis, any stab wound injury has the potential for urethral injury. The largest series examining both assault and self-inflicted stab wounds to the penis found a 17 % urethral injury rate [22].

Penile amputation is a devastating injury that can be a result of assault or circumcision, but most frequently is self-inflicted. The largest series of penile amputations is from an epidemic in Thailand in the 1980s, with more than 100 cases reported. Most of these amputations were performed by disgruntled wives of philandering husbands [75]. Iatrogenic amputation of the penis is rare and usually is a result of a circumcision injury with removal of excess penile skin or a glansectomy [76–79]. Self-inflicted penile amputation is a result of a psychotic event in 87 % patients, with schizophrenia (51 %) and depression (19 %) the most common causes [32]. The underlying delusions in psychotic patients often involve sexual or religious themes. Men who were not psychotic at the time of their penile amputation most often exhibit a personality disorder or transsexual issues that remained unsettled [32].

Another form of self-mutilation that does not involve penile amputation is the placement of foreign bodies in or around the penis. Staples, paper clips, and other sharp objects can all be placed into the glans or corpora cavernosa

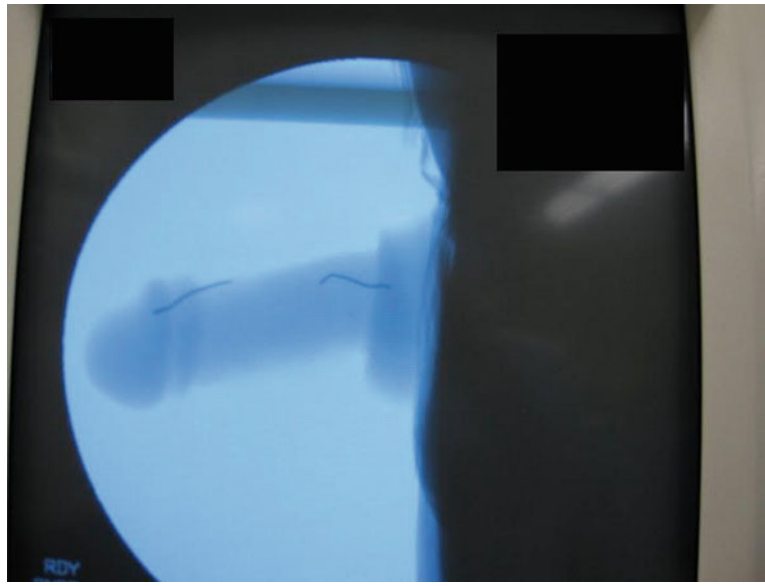

Fig. 7.3 Fluoroscopic images of penis. Self-mutilation of placing staples into the corpora cavernosa

(Fig. 7.3). As with other forms of self-mutilation, it is thought that underlying psychosis and delusions account for the vast majority of these cases. Additionally, constriction rings can be placed around the penis and can become impossible to remove without surgical intervention. When metal rings or tubing are placed around the penis, and removal with a bolt cutter is unsuccessful, surgical removal with an angle grinder may be necessary. In this situation, metal spatulas, wet towels, and cool running water can be used to minimize injury to the penis as metal sparks and thermal injury are possible [80].

Penile Bites

Mammalian bites to the penis are exceedingly rare, as reflected in the small series and case reports in the literature. Bites to the penis can result in genital skin loss, infection, injury to the urethra, and partial or complete loss of the organ. Urethral injury rarely occurs, with no reported cases from a large Level I trauma center [22]. The risks of infectious complications from animal and human bites are perhaps the most common and potentially devastating injuries and generally are the result of delays in presentation. The infectious organisms and potential complications related to genital bites were discussed in the section discussing "Pathophysiology of Trauma to the Scrotum and Testicles: Scrotal Bites."

Penile Avulsion

Avulsion injuries to the penis can result from a variety of mechanisms as previously discussed, but most frequently occur as a result of power machinery accidents, when clothing becomes entrapped in moving parts (penis is trapped by stationary object), or in deceleration injuries (bicycles, motorcycles, motor vehicle accidents). Degloving injury to the penile skin and dartos is the most frequent avulsion injury, with variable amounts of skin being involved (Fig. 7.4) [81]. More severe injuries to the penis in which the corpora are injured or even avulsed off the pubic bone are more likely to occur in machinery accidents [82].

Penile Burns

Burns of the penis are a potentially devastating injury both physically and psychologically. Burns of the penis present in similar manner to the

Fig. 7.4 Blunt trauma to the penis in a bicycle accident resulting in an avulsion injury to the penis

scrotum as already mentioned in the section "Pathophysiology of Trauma to the Scrotum and Testicles: Genital Burns." Careful and prompt evaluation is critical to managing these injuries.

Initial Evaluation of Penile Trauma

Delayed presentation of penile injury is common as many patients feel embarrassed about the nature of their trauma. A thorough history and physical examination is instrumental in making the proper diagnosis for traumatic penile injuries and elucidating potentially more severe injuries that may not be initially appreciated on examination. Determining the mechanism of injury, whether blunt, penetrating (type of weapon involved), bite, or burn, helps identify patients with potentially more significant injuries and risk of infectious complications. In addition to a history and physical exam, a urinalysis is mandatory in all patients with trauma to the penis.

Penile Fracture/Penetrating Injury

Penile fracture classically presents with the patient hearing a snapping or popping sound during missed intromission or acute bending of the penis. This is quickly followed by acute pain and immediate detumescence. Occasionally, a palpable defect in the tunica is felt. As previously mentioned, hematoma is confined to the penis in a classic "eggplant deformity" when Buck's fascia is intact and will spread to the scrotum and perineum if this investing fascia is disrupted. Penetrating injuries to the penis can be complex due to the flaccid nature of the penis. What Information regarding the type of weapon used (i.e., gun or knife) size of the bullet, and proximity of shooter are all helpful pieces of information for further treatment.

Imaging of the corpora cavernosa with contrast cavernosography has limited sensitivity and specificity and is not recommended in the workup of blunt and penetrating penile injuries [6]. A high index of suspicion is necessary for all penetrating injuries to the penis as there is a high rate of associated urethral, scrotal, testicular, bladder, and rectal injuries. CT of the abdomen and pelvis with or without cystography may be performed in stable patients with penetrating injuries who do not require immediate surgery. Blood at the meatus, gross hematuria, or inability to void imply a urethral injury and warrant further investigation with either a retrograde urethrogram or cystoscopy. Surgical exploration of all suspected penile fractures and penetrating injuries will ensure that all urethral injuries are identified.

Penile Amputation

The initial evaluation of a patient with an amputated penis should focus on stabilization of the patient and assessment of the amputated organ. Successful replantation of an amputated penis requires a properly preserved organ. The amputated penis should be thought of as a free flap, where hypothermia prolongs the ischemic survival times [83]. The amputated penis should be placed in a saline-soaked gauze in a clean plastic bag and sealed. This bag should then be placed into a second plastic bag filled with ice slush [84]. Successful replantation has been performed after 18 h, even with prolonged periods of warm ischemia. An attempt to salvage the organ is reasonable up to 24 h in cases of cold ischemia [83, 85, 86]. Patients who are candidates for penile replantation must be properly consented for surgery. In preparation of surgery, patients should be well hydrated and kept warm in order to peripherally dilate their vasculature.

Management of Scrotal, Testicular, and Vulvar Injuries

Blunt Scrotal Trauma

Blunt trauma to the scrotum should be managed in a standardized fashion in order to minimize missed injuries and complications. All patients with blunt trauma should have a scrotal ultrasound to evaluate for rupture of the tunica albuginea, testicular dislocation, hematocele, testicular hematoma, and testicular avulsion. Surgical exploration is warranted if there is ultrasonographic evidence of testicular rupture, dislocation, avulsion, large intratesticular hematoma, expanding scrotal hematoma, or if the integrity of the tunica albuginea cannot be determined. This standardized approach for early operative intervention of blunt scrotal trauma has led to a testicular salvage rate of 83–91 % [14, 24]. Most intrascrotal hematomas and hematoceles, in the absence of testicular rupture, can be managed conservatively with ice, analgesia, compression, and elevation. Thus, traumatic scrotal hematomas associated with normal testicles on ultrasound should not be explored. Attempts to evacuate the hematoma are usually unsuccessful as the blood has infiltrated through the multiple scrotal layers. As previously described, any patient with scrotal trauma should undergo a retrograde urethrogram if indicated.

Scrotal Exploration

The goals of scrotal exploration include preservation of testicular tissue for hemostasis, hormonal function and fertility, cosmesis, prevention of infection and necrosis, decreased pain, theoretical prevention of antisperm antibodies, shorter hospital stay, and a shorter time to convalescence [5, 12, 14, 21, 24]. Bilateral testicular exploration is best performed with a midline vertical incision, allowing visualization of all the scrotal contents. During exploration, the testes, vas deferens, spermatic cords, and epididymes are inspected.

If injury to the spermatic cord is discovered, the incision should be extended toward the groin. If the testis is not viable, an orchiectomy is performed, ligating the vas deferens and spermatic cord separately. If the testicle is viable, and the vas deferens is injured, both ends are debrided and ligated with nonabsorbable sutures to allow identification at the time of delayed microsurgical repair [87, 88].

Repair of the ruptured testis must address parenchymal extrusion and swelling. In ruptured testicles that are salvageable, extruded seminiferous tubules are debrided to healthy tissue to allow closure of the tunica albuginea. A continuous 3-0 slowly absorbable suture is sufficient. If the tunica albuginea cannot be closed primarily, a tunica vaginalis flap can be used to cover the defect [89].

In cases of testicular dislocation, immediate surgical relocation is recommended to avoid complications of atrophy and subsequent infertility [90]. When the dislocated testis is high in the scrotum, manual reduction can be attempted under sedation [91]. However, if this fails, and in all other cases, surgical exploration and orchidopexy is warranted [92].

After surgical exploration, a penrose drain is brought through a separate incision when hemostasis is an issue. The drain can usually be

removed after 24 h. Fluffed gauze and a scrotal supporter should be used to keep the scrotum elevated.

Blunt Vulvar Trauma

Blunt injuries of the vulva most frequently cause labial hematomas. Small hematomas can be managed conservatively, while large hematomas may need to be surgically drained. Lacerations of the vulva may be closed primarily after irrigation and debridement. Interrupted absorbable sutures will allow any accumulated fluid collection to drain from the incision. In the rare situation where hemostasis is poor, the wound may be packed temporarily.

Penetrating Scrotal Trauma

Spermatic Cord and Testicular Trauma

Penetrating injuries of the scrotum require surgical exploration, using techniques previously described. Any penetrating bites, lacerations, or gunshot wounds are debrided, and all devitalized tissues removed. Copious irrigation with saline and bacitracin will help to remove any debris and foreign bodies from the wound in hopes of decreasing infectious complications.

Testicular salvage rates are 23–65 % with penetrating injuries to the spermatic cord, with particularly poor salvage rates for autocastration (23 %) [22, 28, 74]. Microsurgical reconstruction of the severed spermatic cord and vas deferens can be attempted within 6 h of the injury. In testicular avulsion from a stretching type mechanism (i.e., machinery), testicular salvage is extremely unlikely and the spermatic cords should be ligated.

Testicular rupture from gunshot wounds results in a salvage rate of 35–75 % [22, 74, 93]. In contrast to blunt trauma, the defect produced by a gunshot wound is often difficult to close. As previously mentioned, if the tunica albuginea cannot be closed primarily, a tunica vaginalis flap can be used to cover the defect [89]. Testis reconstruction with a synthetic graft should be avoided as those patients have an unacceptably high rate of infection and subsequent orchiectomy [89].

Abrasions, Lacerations, and Avulsions of the External Genitalia

Trauma to the scrotum and penis spans the spectrum from an abrasion, to laceration, and complete avulsion. The majority of scrotal and penile lacerations can be closed primarily, with exceptions in cases of grossly contaminated wounds, associated rectal injuries, or if there was prolonged delay between the injury and presentation for care. Lacerations and avulsions must be vigorously irrigated with removal of all foreign bodies, and the wound edges debrided to remove any potentially devitalized tissue.

The management of avulsions is different from lacerations. If allowed to heal by secondary intention, the testicles or penis would become fixed in scar tissue. Scrotal avulsion injuries involving less than 60 % of skin loss can be closed primarily or in a delayed fashion depending on whether the wound was grossly contaminated. When greater than 60 % of scrotal skin is avulsed, split-thickness skin grafting or reconstruction with a pedicled thigh flap is necessary for adequate genital coverage [94–97]. Similarly, penile avulsion (degloving) injuries can often be closed primarily when the injury is not circumferential (Fig. 7.5). Split-thickness skin grafting is appropriate for circumferential penile avulsion injuries or when large skin defects cannot be closed without tension.

When the mechanism of avulsion is from the shear forces of a motor vehicle collision, the area may rarely be suitable for cleansing and preparation for immediate split-thickness skin grafting. However, this approach is not preferred when the mechanism of avulsion is due to an animal bite or rotating machinery. Initial wound management with wet to dry dressing is performed to allow the demarcation of viable tissue. Care must be taken to ensure the wound is clean with healthy skin edges, free from infection, and with robust granulation tissue before scrotal reconstruction can be performed. If prolonged wound care is necessary before scrotal

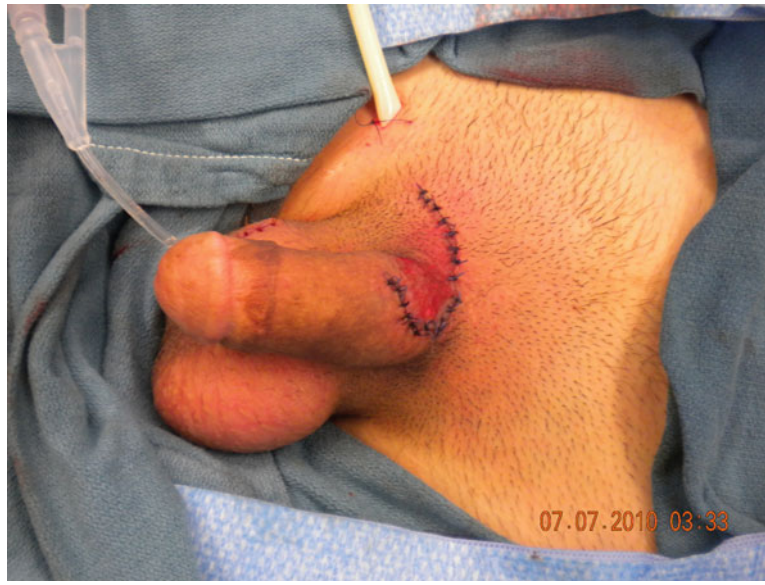

Fig. 7.5 Primary closure of the penile avulsion injury

reconstruction, or if the patient is unable to tolerate the pain of dressing changes, the testes can be placed in subcutaneous thigh pouches.

Management of Bites to the External Genitalia

Bites to the external genitalia often result in a polymicrobial genital infection. These patients require broad spectrum antibiotics, including the use of a penicillin or cephalosporin, to provide coverage against a host of possible aerobic and anaerobic pathogens including *Clostridial*, *Pasteurella*, *Streptococci*, and *Actinomyces* species [98]. In addition to local wound debridement and saline irrigation, all patients should receive appropriate prophylaxis against potential infectious diseases. Patients should receive a tetanus vaccination regardless if their bite was of animal or human origin. If rabies is suspected in an animal bite, vaccination with rabies immunoglobulin and human diploid cell vaccine is recommended [99, 100]. Because human bites pose the unique risk of contracting sexually transmitted diseases, all patients should be tested for hepatitis B and C, as well as human immunodeficiency virus. Appropriate disease prophylaxis should be initiated immediately to reduce the spread of these diseases. After debridement and irrigation, wounds without obvious signs of infection or devitalized tissue may be closed, while more complicated wounds should be left open and treated with wet to dry dressing changes until all signs of infection and devitalized tissue have been managed.

Management of Burns to the External Genitalia

The management of patients with genital burns must occur in conjunction with a burn team, because the majority of patients have a larger total body surface area burn. The initial assessment should determine the type and depth of the burn and focus on fluid resuscitation and infection control. Chemical burns should be copiously irrigated with saline to remove any substances remaining on the skin. Acidic burns should then be irrigated with sodium bicarbonate, while alkaline burns should be irrigated with dilute acetic acid. Electrical burns should be managed conservatively for the first 24 h to determine the extent of tissue injury. Additional treatment of electrical burns is similar to thermal burns.

First-degree and superficial second-degree thermal burns should be irrigated with saline and will reepithelialize over time with conservative management. Deep second-degree thermal burns may need excision of bullae larger than 2 cm in order to minimize infection. Antibiotic creams (1 % silver sulfadiazine, 0.5 % silver nitrate, or mafenide acetate) should be applied to deep second-degree and third-degree thermal burns. Third-degree wound management requires eschar excision and antibiotic creams and may take several weeks before the wound is healthy enough to support a skin graft. Once the wound is free of infection and with healthy granulation tissue, split-thickness skin grafting can be performed in a meshed fashion. Whether the penile or scrotum split-thickness skin graft is meshed in a 1:1 or 2:1 fashion is determined by the amount of skin needed to graft all the body's burn sites and the relative availability of skin for grafting.

Split-Thickness Skin Grafting of the External Genitalia

Traumatic injuries resulting in genital skin deficiency are best managed with split-thickness skin grafts. These grafts have been used for scrotal reconstruction for more than 50 years [101]. Prior to grafting, the host bed must be free of infection, and all healthy granulation tissue excised. If grafting a neo-scrotum, the testicles and spermatic cords should be sutured together to prevent the testicles from being able to "swing" above the penis. Split-thickness skin grafts contain the epidermis and part of the dermis, and thus do not grow hair. Graft are harvested at 0.014–0.018 in. thickness (to minimize contracture) and meshed in either a 1:1 or 2:1 fashion depending on the availability of donor skin and overall graft requirements of the patient [94]. Meshing the graft improves its chance for take, increases the surface area grafted without compromising cosmesis (mimics scrotal rugae), and allows exudates to drain from the host bed. When grafting the penis, it is important to have the penis on maximal stretch when circumferentially placing the graft in order to avoid contraction, shortening, or deviation of the penis with erection. Grafts must be placed on the genitalia to ensure direct, flat contact between the graft and bed. Skin grafts must be completely immobilized as survival is dependent on imbibition and inosculation. After the grafts are adequately secured, a dressing bolster is created consisting of nonadherent Conformant (Smith and Nephew Inc.) and gauze. This is soaked in mafenide acetate and tightly applied to the graft. The bolster is kept moist with mafenide acetate every 6 h and left in place for 5 days. To ensure graft immobilization, patients are kept on bedrest or limited activity until the bolster is removed.

Management of Penile Injuries

Blunt Trauma

Blunt penile trauma to the flaccid penis usually results in a subcutaneous hematoma without injury to the tunica albuginea. These injuries can be managed conservatively with ice packs and analgesia. Significant preputial swelling may make voiding difficult. If this situation arises, urethral catheterization may be required until the swelling subsides.

Penile Fracture

Penile fracture is an emergency and should be treated surgically even in cases of delayed presentation. El-Assmy et al. showed that patients with delayed presentation up to 7 days, when treated surgically, had no difference in outcomes compared to patients treated within 24 h [102]. Conservative management of these injuries is not recommended as penile fibrosis and angulation develop in as many as 35 % of patients [62]. Retrograde urethrography or cystoscopy, when indicated, will exclude a urethral injury. A circumferential subcoronal incision and degloving of the penis provides exposure of both corpora and the urethra. For more proximal injuries a penoscrotal incision can be made and the penis degloved by everting the penis through the incision. A subcoronal incision is generally preferred as this allows complete inspection of both corpora, ensuring all defects are repaired.

Tears in the corpus spongiosum are possible with a negative retrograde urethrogram and cystoscopy, and thus a careful inspection of the corpus spongiosum is mandatory. Occasionally, a transversely oriented tear in the tunica can extend behind the corpus spongiosum, or rarely dorsally under the neurovascular bundle. In these situations, the corpus spongiosum or neurovascular bundle must be mobilized and retracted to allow adequate visualization of the injury. The tunica albuginea is repaired with interrupted 3-0 slowly absorbable sutures, and the skin closed with interrupted 4-0 chromic sutures.

Penetrating Penile Trauma

Gunshot and Stab Wounds

All patients with penetrating injuries to the penis require surgical exploration except in tangential, superficial injuries that clearly do not involve structures beyond dartos [22]. As previously discussed, a high index of suspicion for an associated injury is pertinent in all patients. A retrograde urethrogram and cystoscopy should be performed as indicated. A circumferential subcoronal incision is preferred for optimal exposure of all the penile structures and corpus spongiosum. If an injury is suspected proximal to the suspensory ligament or crus of the penis, a penoscrotal or perineal incision may be warranted. All wounds in the skin and corpora should be debrided, and copiously irrigated with saline. An exception may be made with low caliber weapons as they can produce a wound with a clean edge that does not require additional debridement and may simply be irrigated before wound closure. The majority of tunica albuginea defects can be primarily repaired. In cases of extensive tissue loss, autologous rectus fascia can be used to cover large corporeal defects [103]. Split-thickness skin grafts can be used to close areas of extended penile shaft skin loss after infection control has been attained [88]. In extensive penile injuries involving the urethra, a suprapubic cystotomy tube may be required.

After surgical repair of both blunt and penetrating penile injuries, a light compressive dressing is applied to minimize swelling. If urethral injury is present, a urethral catheter is mandatory. Sexual activity is contraindicated for 1 month following surgical repair.

Penile Amputation

Microsurgical replantation is the preferred surgical method for the treatment of penile amputation. Transport of patients to centers experienced in these techniques is preferred. As previously discussed, the amputated penis should be placed in a saline-soaked gauze in a clean plastic bag and sealed. This bag should then be placed into a second plastic bag filled with ice slush [84]. First, a two-layer spatulated urethral reconstruction of the urethral mucosa and corpus spongiosum is completed with interrupted slowly absorbable sutures. A urethral catheter is then placed to stabilize the penis. The tunica albuginea of the corpora cavernosa and septum are subsequently anastomosed with small slowly absorbable sutures. The restored corpora cavernosa provides blood flow to the distal corpora, glans, and urethra, while the corpus spongiosum allows some venous drainage of the penis. Lastly, a microsurgical anastomosis of the dorsal arteries, dorsal vein, and dorsal nerves with fine nonabsorbable sutures is performed. Postoperatively, patients are kept in a warm room on bed rest. They maintain urinary diversion, anticoagulation (select cases), aggressive hydration, and monitoring of arterial flow in the distal penis.

If the patient presents without the amputated penis, if the amputated organ is not salvageable, or if the graft bed is not compatible with replantation, reconstructing the penile stump or total phallic replacement are the remaining options. In the acute traumatic situation, hemostasis and infection control are the primary responsibilities of the surgeon. The amount of skin that is removed and penile length remaining will determine in the short term how the urinary stream is managed. In penises with 2–3 cm of length remaining, a widely spatulated neo-meatus is essential to avoid meatal stenosis. This amount of length affords most men the ability to stand to urinate [104]. While this length is usually adequate to urinate, it is often insufficient for sexual intercourse. In cases when there is less than 2 cm of penile length

or when the sexual capacity of the organ is insufficient, penile lengthening procedures or total phallic replacement is necessary.

Summary

A systematic approach to the management of trauma to the external genitalia is essential. The treatment goal for trauma to the genitalia is organ preservation. Knowledge of the anatomy, mechanism of injury, clinical signs and symptoms, imaging findings, and treatment options is critical to ensure successful outcomes. This includes maintenance of fertility, endocrine function, sexual health, micturition, cosmesis, and psychologic well-being. Conservative management may be appropriate in particular situations; however, prompt surgical treatment is often mandatory to minimize complications and optimize patient outcomes. Trauma to the external genitalia often involves multiple organ systems. Maintaining a high index of suspicion for associated injuries while working closely with experts from other medical and surgical teams ensures the greatest patient benefit.

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Part II

Infection

Infection of the Upper Urinary Tract

8

Maxwell V. Meng

Introduction

Infections of the urinary tract are a common problem and associated with significant morbidity and utilization of medical resources. It is estimated that urinary tract infections (UTIs), involving the urethra, bladder, ureters, or kidneys, account for 1 million U.S. hospitalizations each year [1]. The majority of UTIs occur in healthy women and are typically uncomplicated infections of the bladder (cystitis), with management amenable to outpatient oral antibiotics. Nevertheless, up to a quarter of the hospitalizations for UTI involve infection of the kidney or pyelonephritis [2]. In this chapter we discuss infection of the upper urinary tract and appropriate evaluation and management of pyelonephritis as well as more serious sequelae, including abscesses and chronic renal infections.

Pyelonephritis

Pyelonephritis is defined as infection, usually bacterial, of the kidney and renal pelvis with resulting tubulointerstitial inflammation of the renal parenchyma. Even in cases of "uncomplicated" pyelonephritis in women, pyelonephritis itself is considered a complicated infection of the urinary tract [3]. Thus, consideration of an underlying anatomic or functional abnormality of the urinary tract is necessary. This guides the appropriate utilization of imaging studies, antibiotic therapy, and adjunctive interventions to effect a rapid and effective resolution of the infection with minimal morbidity.

Pathogenesis and Pathophysiology

Escherichia coli causes 80 % of all community-acquired UTI in healthy individuals and 50 % of UTI in patients in the hospital or with diabetes [4]. Similarly, *E. coli* is the most common cause of pyelonephritis. Although all individuals are potentially susceptible to UTI and pyelonephritis, certain characteristics increase the risk of complicated infections where there are underlying structural or functional abnormalities of the urinary tract. Table 8.1 summarizes such risk factors. Variables that increase exposure to uropathogens include the presence of foreign body (e.g., catheter) and vaginal intercourse. Variables important in the stratification of risk include gender, age, and underlying conditions affecting the urinary tract, including pregnancy and diabetes [5, 6].

Lower UTIs, namely cystitis, rarely progress to pyelonephritis although the bladder is usually affected during upper UTI. Uropathogenic bacteria that cause pyelonephritis have special characteristics and may be transmitted via the fecal-oral route and person-to-person direct

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Table 8.1 Risk factors for complicated upper urinary tract infection (complicated pyelonephritis)

Men (any UTI)
Nosocomial infections
Women
Anatomic abnormality of urinary tract
Function abnormality of urinary tract
Pregnancy
Spinal cord injury
Comorbid diseases (diabetes, sickle cell disease)
Unresolved UTI
Persistent UTI
Infection with urea-splitting organism
Recurrent febrile UTI as child
Febrile UTI (>3 days)
Renal colic
Gross hematuria

contact, including sexual activity [7]. *E. coli* responsible for UTI exhibits several differences from *E. coli* within the bowel flora. These include P pili, aerobactin, S fimbrial adhesion, and hemolysin [8]. The importance of P fimbriated *E. coli* in acute pyelonephritis has been demonstrated in both children and adults, as well as in the monkey [9–11]. In addition, an association has been found between renal dysfunction and P fimbria receptors in those with renal scarring [12]. The P pili not only cause adherence to the urothelial cells facilitating infection, but they bind to fibronectin in the extracellular matrix. This contributes to the inflammatory response and may be important in the secondary inflammation after epithelial cell injury.

Acute pyelonephritis results in increased interleukin-6 and interleukin-8 levels in both the urine and serum [13]. This activation of the cytokine pathway is dependent on *E. coli* adhesion to the urothelial cells. T lymphocytes and polymorphonuclear cells are recruited to the site of infection by the cytokines and then release enzymes that degrade the extracellular matrix. Thus, the inflammatory response as well as renal damage is mediated by both the local cytokine activation and lymphocyte activation. The combination of multiple virulence factors determines the degree of pathogenicity of the bacteria [14].

Epidemiology

Although UTI in general has been well studied, few reports specifically examine the epidemiology of pyelonephritis. It is estimated that 25–50 % of patients diagnosed with pyelonephritis in the emergency department are hospitalized [15–17]. Nicolle et al. reported that the mean rates of hospitalization for acute pyelonephritis was 10.86 per 10,000 population among women and 3.32 per 10,000 population among men [18]. In women, pregnancy was an important variable while diabetes was a contributor in both men and women. Rates of hospitalization among women aged 20–29 years were similar to those among women 70 years and older.

In a survey from the United States, similar rates of hospitalization were reported—11.7 per 10,000 population among women and 2.4 per 10,000 population among men [19]. Rates of hospitalization increased with age but were not associated with diabetes. Men were found to have higher rates of mortality in the hospital compared with women (16.5 vs. 7.3 per 1,000). Age was the strongest predictor of mortality, with those 60 years and older at highest risk of death. The mean duration of hospitalization and average number of diagnoses per hospital stay both increased with age. Little variation in mortality was observed among various hospital sizes, ownership, location, and teaching status. These data suggest that patient, rather than hospital, characteristics determined outcome and that relatively uniform application of care standards was occurring.

Data from a population-based analysis suggest that the majority of cases now occur in outpatients, with annual rates of outpatient and inpatient pyelonephritis of 12–13 cases per 10,000 population and 3–4 cases per 10,000 population, respectively, in the female population [20].

Diagnosis of Pyelonephritis

Although pyelonephritis is defined as infection within the renal parenchyma, the diagnosis is based on the presence of UTI with associated clinical

features of fever and flank pain. The evaluation for all patients with known or suspected UTI should specifically assess for the presence or absence of fevers, flank pain, prior urinary infection, previous antibiotic use, prior urologic procedures and operations, history of nephrolithiasis, gross hematuria, and medical comorbidities (diabetes, sickle cell disease). Many other terms for acute pyelonephritis have been used and may create ambiguity; these include focal pyelonephritis, lobar nephronia, and focal bacterial nephritis. Other terms, also based solely on radiologic findings, include renal carbuncle and renal phlegmon.

Clinical Presentation

A wide spectrum of clinical findings may be present. Classically, fever and chills are found in conjunction with costovertebral tenderness. Nevertheless, the initial presentation may range from symptoms of cystitis with mild flank pain to frank sepsis [21]. Lower urinary tract symptoms of dysuria, frequency, and urgency may also be present. In a study of patients with recurrent UTI, fever and flank pain were no more diagnostic of pyelonephritis than of cystitis. Physical examination should include measurement of vital signs to determine if evidence of sepsis (hypotension, tachycardia) is present. Because of overlap of symptoms (e.g., nausea, abdominal pain), the differential diagnosis should include appendicitis, perforated viscus, cholecystitis, and pelvic inflammatory disease.

Laboratory Findings

The urinalysis usually shows white blood cells, red blood cells, and white blood cell casts. In most patients, the urine culture will demonstrate greater than 100,000 colony-forming units of bacteria, typically *E. coli*. However, 20 % of patients have cultures with fewer bacteria ($<10^5$) and negative results on gram staining [22]. *E. coli* accounts for over 80 % of cases of acute pyelonephritis. Other members of the Enterobacteriaceae family can be found, including *Klebsiella*, *Proteus*, *Pseudomonas*, *Serratia*, and *Citrobacter*. Gram-positive organisms, such as *E. faecalis*, *S. aureus*, and *S. epidermidis*, may also cause pyelonephritis.

Laboratory tests may show a leukocytosis, increased erythrocyte sedimentation rate, and elevated C-reactive protein levels. Serum creatinine level can be elevated, and some patients present with acute renal failure. Blood cultures may be positive, confirming bacteremia.

Invasive tests are the most reliable method of confirming pyelonephritis; however, these are impractical and therefore not routinely used in most patients. Initially described by Stamey in 1963, ureteral catheterization specifically collects multiple urine specimens from both upper urinary tracts to quantitate bacterial counts. The method is well described in detail elsewhere [23] and validated in multiple studies. Subsequently, Fairley described the bladder washout test to help differentiate upper from lower UTI [24]. The technique is simpler, with determination of bacterial counts from the urine after washing the bladder with a combination of neomycin and two lytic enzymes. Currently, noninvasive tests to localize infection to the kidneys are not reliable. Documenting true upper UTI is typically reserved for patients with recurrent or persistent infections where the information determines subsequent treatment decisions.

Treatment of Pyelonephritis

Despite the recognition of acute pyelonephritis as a significant infection, limited data are available regarding the optimal antimicrobial regimen (Fig. 8.1). Nevertheless, a shift in the treatment paradigm has been observed in recent years with primary outpatient management employing oral antibiotics. This is appropriate in stable patients with uncomplicated acute pyelonephritis. Oral fluoroquinolones are the first-line drugs, with broad-spectrum activity and excellent urinary levels of drug. Table 8.2 summarizes effective oral regimens for uncomplicated pyelonephritis. Although previous studies have examined the efficacy of trimethoprim-sulfamethoxazole (TMP-SMX) and ampicillin for pyelonephritis, these should currently not be used alone for empiric therapy, unless the organism is known to be sensitive; there is a high prevalence of

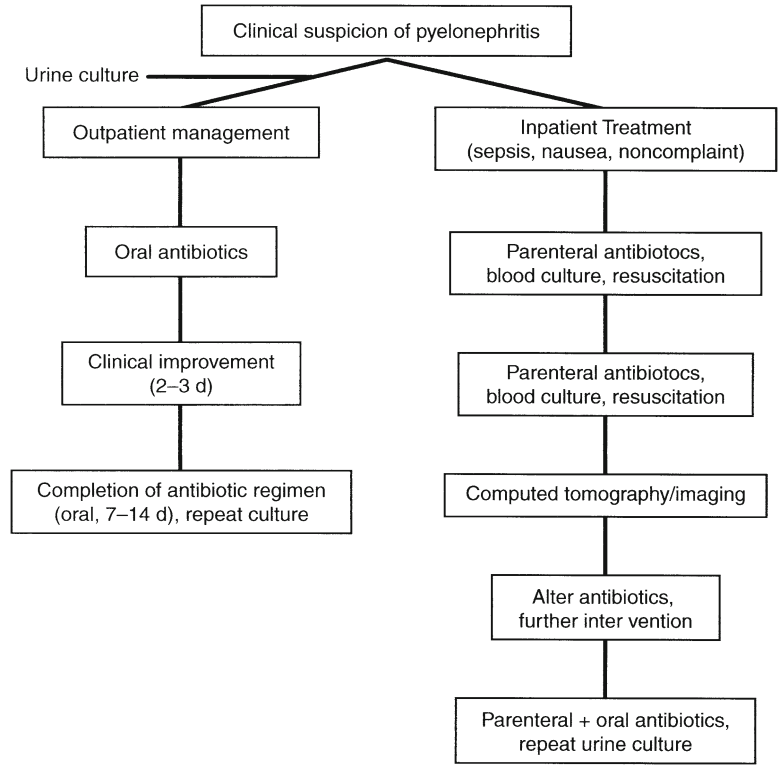

Fig. 8.1 Treatment algorithm for acute pyelonephritis

Table 8.2 Oral antibiotic regimens for acute pyelonephritis (uncomplicated)

Drug (dose)	Interval (h)	Duration (days)
Amoxicillin (500 mg)	q8	10–14
Amoxicillin (875 mg)	q12	10–14
Amoxicillin-clavulanate (875/125 mg)	q12	10–14
Ciprofloxacin (500 mg)	q12	7
Ciprofloxacin (1,000 mg)	q24	7
Levofloxacin (750 mg)	q24	5
TMP-SMX (160/800 mg)	q12	14

resistance to TMP-SMX among uropathogens [25]. Nitrofurantoin should not be used because it does not achieve reliable serum or tissue levels. Many current fluoroquinolones can be used, but moxifloxacin has lower urinary levels and should be avoided for pyelonephritis. If gram-positive cocci are seen on the gram stain, amoxicillin or amoxicillin-clavulanic acid should be added, or used alone if the culture confirms enterococcus susceptible to ampicillin.

Czaja et al. found that among *E. coli* strains, from 1997 to 2001, the rate of ciprofloxacin resistance increased from 0.2 to 1.5 % of isolates while the rate of TMP-SMX resistance decreased from 25 to 13 % [20].

Traditionally, women with pyelonephritis have been treated for up to 6 weeks with antibiotics, but several studies have shown that shorter courses are equally efficacious. The IDSA clinical practice guideline committee analyzed available reports regarding treatment for pyelonephritis [26]. TMP-SMX was preferred to ampicillin, and 2 weeks of therapy was adequate for most women. In a randomized, prospective trial including TMP-SMX, 6 weeks of therapy was no better than 2 weeks and associated with more side effects [27]. Additional studies also suggest that 10–14 day regimens are sufficient [28]. Talan et al. compared the efficacy of ciprofloxacin (7 days) with TMP-SMX (14 days) in treating uncomplicated acute pyelonephritis [29]. Bacteriologic cure rates at 4–11 days were

99 % for ciprofloxacin and 89 % for TMP-SMX ($p = 0.004$); clinical cure rates were 96 % and 83 %, respectively. The ongoing FUTIRST trial seeks to determine whether 7 days of antibiotic treatment is inferior to the traditional 14 day course for community-acquired febrile UTI [30].

In reliable patients with moderate symptoms (e.g., fever, vomiting), temporary intravenous hydration and parenteral antibiotic dosing (i.e., fluoroquinolone, ceftriaxone, aminoglycoside) can be safely initiated with subsequent outpatient oral antibiotic regimen. In these situations, early follow-up is essential and persistent or worsening symptoms should prompt a return visit. In all cases of acute pyelonephritis, urine cultures should be checked at 48 h to ensure that the organism is sensitive to the selected antibiotic. Repeat urine cultures are performed 5–7 days after starting therapy and 4–6 weeks after completion of antibiotics to confirm that the infection has resolved. A significant number (10–30 %) of patients relapse after 10–14 days of adequate antibiotics, and require a second 14 days course; rarely, 6 weeks of antibiotics are necessary to eradicate the renal infection [31, 32].

Pyelonephritis Necessitating Hospitalization

A significant minority of patients with pyelonephritis requires hospitalization for parenteral antibiotic therapy. Indications for admission in those with uncomplicated pyelonephritis include the inability to maintain oral fluids or medication, uncertain social situation, poor compliance, and uncertain diagnosis. Moreover, those with uncomplicated pyelonephritis and normal urinary tracts but severe infection warrant admission for antibiotic and supportive therapy. Patients with complicated pyelonephritis require hospitalization more often; criteria include infection in men, hospital-acquired infection, urinary tract abnormality, nephrolithasis, and catheterization or instrumentation. It is generally recommended that pregnant women with pyelonephritis be observed during initiation of antibiotics.

After urinary cultures have been obtained, parenteral therapy is chosen. Tables 8.3 and 8.4 summarize appropriate regimens for uncomplicated pyelonephritis in the severely ill patient and complicated pyelonephritis, respectively. Common options include fluoroquinolone, aminoglycoside with or without ampicillin, or extended-spectrum cephalosporin. Complicated infections and those due to nosocomial pathogens require broad-spectrum coverage, typically an aminoglycoside and ampicillin; consideration must be given to the possibility of gram-positive organisms. Urine and blood cultures are obtained after initiating therapy, and antimicrobials should be altered based on the results of susceptibility testing.

Table 8.3 Parenteral antibiotics for acute pyelonephritis (uncomplicated)

Drug (dose)	Interval (h)
Ceftriaxone (1–2 g)	q24
Cefotaxime (1–2 g)	q8
Ceftazidime (2 g)	q8
Cefepime (1 g)	q12
Ciprofloxacin (400 mg)	q12
Gatifloxacin (400 mg)	q24
Levofloxacin (750 mg)	q24
Gentamicin (5–7 mg/kg)	q24
Gentamicin (1 mg/kg)	q8
Ampicillin (1 g)	q6
TMP-SMX (160/800 mg)	q12
Aztreonam (2 g)	q6
Ampicillin-sulbactam (1.5 g)	q6
Piperacillin-tazobactam (3.375 g)	q6

Table 8.4 Parenteral antibiotics for acute pyelonephritis (complicated)

Drug (dose)	Interval (h)
Ampicillin (2 g)	q6
Gentamicin (5–7 mg/kg)	q8
Ciprofloxacin (400 mg)	q12
Levofloxacin (500 mg)	q24
Ticarcillin-clavulanate (3.1 g)	q8
Imipenem-cilastatin (500 mg)	q6–8
Aztreonam (1 g)	q8

Patients may have persistent symptoms and fevers despite the initiation of appropriate antibiotic treatment, and observation is warranted for 48–72 h. After resolution of symptoms in the absence of bacteremia, conversion to oral antibiotics after 2–3 days is indicated to complete 7–14 days of therapy. If the blood cultures are positive,

parenteral antibiotics should be continued for 7 days, with subsequent completion of oral antibiotics to 7–14 days [26]. When clinical improvement does not occur at this point, further evaluation is needed. Imaging, discussed later, should be obtained to identify potential urinary obstruction or renal and perirenal abscesses. Urinary drainage can be accomplished by placement of either ureteral stent or percutaneous nephrostomy tube. A recent study developed and validated clinical prediction rules for identifying which patients with febrile UTI needed radiologic imaging. Using the criteria of history of urolithiasis, urine pH ≥7.0 and/or renal insufficiency (glomerular filtration rate ≤40 mL/min/1.73^3) imaging was reduced by 40 % yet still maintain negative and positive predictive values of 93 % and 24 %, respectively, for urgent urological disorders such as pyonephrosis or abscess [33].

Urosepsis

The incidence of serious infections in hospitalized patient has increased over the past 3 decades. Gram-negative bacterial infection is the most common cause of sepsis and carries an overall mortality in excess of 10 % [34, 35]. Although bacteremia resulting from UTI and pyelonephritis can be managed with appropriate antibiotic therapy alone, sepsis syndrome and septic shock are dire conditions necessitating emergent intervention.

Sepsis syndrome is defined as clinical evidence of infection associated with hyper- or hypothermia (>38 °C or <36 °C), tachycardia (>90/min), tachypnea (>20/min), and evidence of inadequate organ perfusion [36]. Septic shock is the sepsis syndrome and hypotension (<90 mmHg) despite adequate volume replacement. The pathophysiology of sepsis has been studied extensively and arises from the vigorous host response to gram-negative infection [37]. The release of pro-inflammatory cytokine mediators by lipopolysaccharide-responsive cells (macrophages, endothelial cells) is initiated primarily by endotoxin, a lipopolysaccharide component of the bacterial outer membrane. Lipid A, a component of endotoxin, induces release of factors including tumor necrosis factor alpha, interleukin-1, interleukin-6, and interleukin-8. The intravascular activation of the inflammatory pathway via the cytokine overproduction results in the hemodynamic collapse.

After sepsis is diagnosed or suspected, aggressive supportive care is needed (see Chap. 1). All potential sources of bacteremia must be cultured and appropriate broad-spectrum antibiotics administered. Volume resuscitation, ventilatory support, and hemodynamic monitoring and management may be required. The urinary tract should be studied with imaging to determine whether obstruction or stasis is present, or whether abscess formation has occurred.

Imaging for Pyelonephritis

Routine upper urinary tract imaging is not indicated in patients with pyelonephritis. However, persistence or worsening of symptoms at 48–72 h requires further evaluation. The intravenous urogram (IVU) has limited utility in individuals with pyelonephritis. Generalized or focal renal enlargement may be noted and can mimic a renal mass. Delayed appearance of the nephrogram may result from infection of the renal parenchyma. However, the IVU is negative in up to 75 % of patients with pyelonephritis [38]. Ureteral obstruction may be evidence on IVU, although dilation of the collecting system, without obstruction, may be seen with acute pyelonephritis.

Renal ultrasonography is noninvasive and without ionizing radiation, but in cases of upper UTI, information gained is limited [39]. Renal size and shape are apparent, and dilation of the collecting system can be detected. Focal areas of infection, with enlargement or suggestion of a mass, may be evident. Typically acute pyelonephritis appears as a hypoechoic area, but can appear hyperechoic with or without loss of normal corticomedullary junction differentiation. Echogenic material within the dilated renal pelvis may suggest pyonephrosis, often with a urine-debris level. A recent study found utility of ultrasound performed for acute pyelonephritis in the emergency department setting.

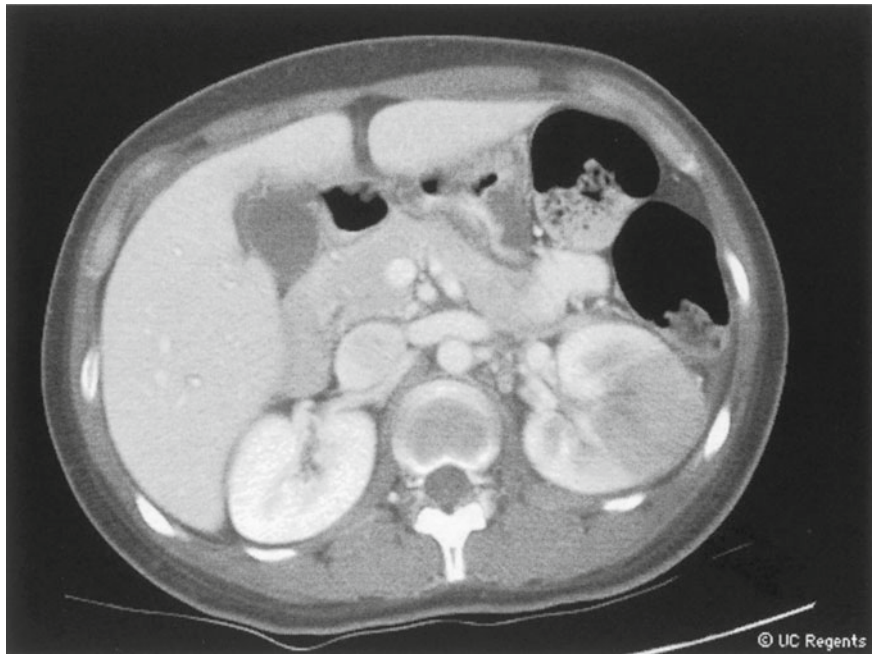

Fig. 8.2 Contrast-enhanced CT demonstrating evidence of left pyelonephritis. Note the enlarged renal contour, compared to the right side, as well as the wedge-shaped area

The combination of plain radiograph and ultrasound identified significant abnormalities in 57 %, comparable to computed tomography (CT) (59 %); in cases of complicated pyelonephritis, the rate of ultrasound detected abnormalities increased to 61 %. Moreover, the findings on ultrasound could direct appropriate intervention, such as percutaneous nephrostomy, abscess aspiration, lithotripsy, or nephrectomy, in 34 % [40].

CT provides the most detailed images of both acute pyelonephritis and associated findings and sequelae, and it is the study of choice for investigation of pyelonephritis (Fig. 8.2). If the infection is sufficiently severe, global or focal renal enlargement can be visualized. Edema and inflammation may result in decreased attenuation of the affected parenchyma on non-contrast scans. After intravenous contrast administration, wedge-shaped or linear zones of decreased attenuation radiating from the calyces towards the renal capsule are consistent with acute pyelonephritis, the result of tubular obstruction by inflammatory cells and debris, ischemia, and interstitial edema. In diffuse pyelonephritis, poor enhancement of the parenchyma and delayed contrast excretion can be found. Less common CT signs include thickening of the pelvicalyceal wall, obliteration of the renal sinus and perinephric fat planes, and thickening of Gerota's fascia.

It is important to note that acute pyelonephritis may appear as focal, mass-like areas of decreased enhancement on CT. Delayed CT images may help differentiate an inflammatory mass from tumor. In addition, repeat CT after resolution of infection should be performed if the diagnosis of malignancy remains uncertain.

Renal Abscess

A renal abscess is a focal collection of pus confined to the renal parenchyma. Currently, these lesions primarily arise from progression of acute pyelonephritis caused by gram-negative organisms. Prior to the antimicrobial era, most renal abscesses resulted from hematogenous spread of staphylococci infection [41]. These abscesses, or carbuncles, occurred in higher risk patients with dialysis,

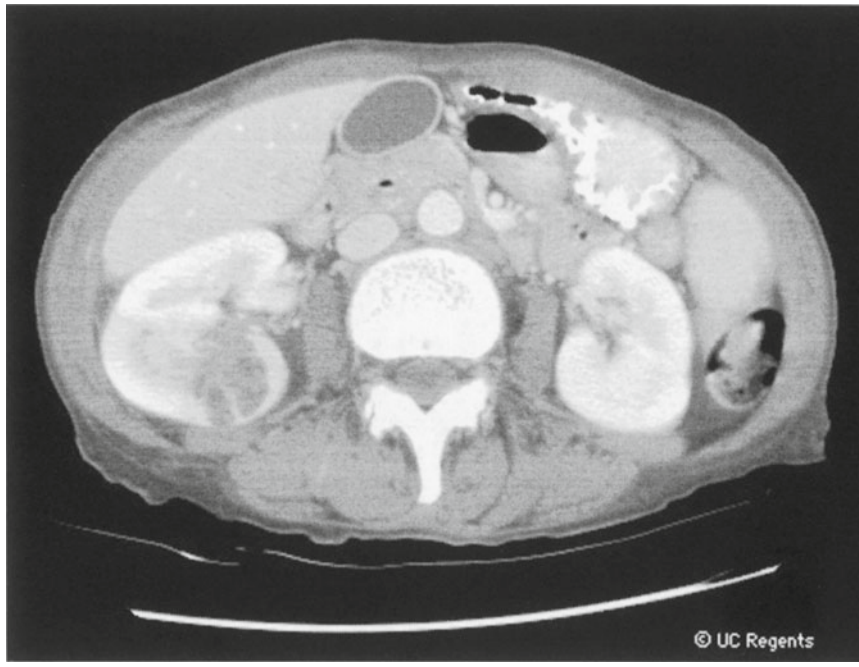

Fig. 8.3 Contrast-enhanced CT demonstrating evidence of right pyelonephritis and abscess formation. Note the posterior region of reduced attenuation, consistent with pyelonephritis, and the multiple septae within the abscess

diabetes, and intravenous drug use. Carbuncles also occurred more frequently in men, typically involving a single unilateral lesion.

A large, population-based cohort study from Taiwan found that diabetes increased the risk of hospitalization for renal abscess (HR 3.81), particularly in younger diabetic patients, and that women (HR 2.78) and those from remote, less urbanized areas (HR 1.17) were at great risk [42].

Presentation and Diagnosis

Most patients present with signs and symptoms consistent with acute pyelonephritis; however, in some patients the symptoms are subtle and diagnosis may be delayed until surgical intervention. In addition to a history of UTI, abscess formation is associated with urinary stasis, calculi, pregnancy, neurogenic bladder, and diabetes [43]. Evidence of skin infections or intravenous drug use may suggest the dissemination of gram-positive organisms via the blood stream.

Abscesses appear as hypoechoic or anechoic complex masses with increased through transmission on ultrasonography. Early abscess formation, however, may be difficult to distinguish from acute pyelonephritis. As the abscess encapsulates, the borders become increasingly well defined and evolve into a distinct mass. Debris within the abscess appears as internal echoes, but the degree of fluid and solid appearance can vary greatly.

CT is the most accurate method of identifying renal abscesses, which appear as a low-density mass [44, 45] (Figs. 8.3 and 8.4). The lesions are apparent on both pre- and post-contrast images, with the pseudocapsule more evident after contrast enhancement; the debris and pus does not enhance. The presence of a chronic abscess leads to obliteration of adjacent tissue planes and thickening of Gerota's fascia.

Treatment

In the past, surgical drainage and debridement, and occasionally nephrectomy, were required for renal

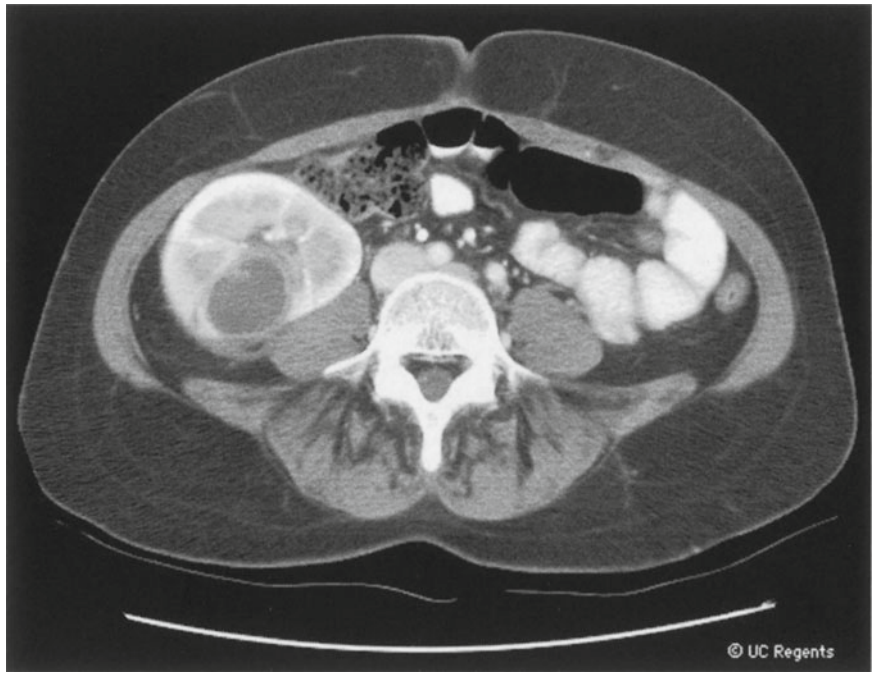

Fig. 8.4 Contrast-enhanced CT with right renal abscess. Note the appearance of the pseudocapsule of the abscess cavity

abscesses. Contemporary management of renal abscesses begins with parenteral antibiotics and close observation. If a urinary source is suspected, then antibiotic selection is initiated as described previously for gram-negative organisms. If hematogenous spread from the skin is suspected, coverage of *Staphylococcus* with a penicillinase-resistant penicillin, cephalosporin, or vancomycin is necessary. CT is crucial in identifying the lesion and its size. Abscesses smaller than 3 cm are usually amenable to intravenous antibiotics alone [46]. After clinical improvement, intravenous antibiotics should be continued for 24–48 h. Subsequently, an additional 2 weeks of oral antibiotic therapy should be completed with radiographic confirmation of cure. In the immunocompromised patient, early consideration of percutaneous aspiration or drainage may hasten resolution of infection and recovery. Abscesses 3–5 cm are amenable to percutaneous, image-guided drainage [47, 48]. Dalla Palma et al. described successful medical treatment of renal abscesses less than 5 cm, without evidence of complications [49]. Antibiotic therapy was continued for at least 4 weeks and follow-up CT was important. Traditionally, larger abscesses (>5 cm) required open surgical drainage and potentially nephrectomy. Improvements in interventional radiologic techniques permit the percutaneous management in many of these patients, with decrease in morbidity. This must be balanced against the potential for prolonged hospitalization, multiple procedures, and unknown long-term sequelae.

Perinephric Abscess

Suppurative infections surrounding the kidney, within the perinephric space, are difficult to diagnose and treat. Most perinephric abscesses result from an underlying renal infection with abscess development and rupture within Gerota's fascia; subsequent breach of Gerota's fascia and spread leads to paranephric abscesses. These purulent collections surrounding the kidney may also arise from a hematogenous source or primarily from an adjacent organ, such as the bowel, pancreas, pleural space, and gallbladder [41].

A variety of bacterial organisms can lead to perinephric abscess formation. Similar to renal abscesses, early studies document a significant number of staphylococcal infections, with modern series reporting a greater number of infections attributable to *E. coli* and *Proteus*. Urine culture most reliably detects the organism, with blood and abscess fluid only 50 % sensitive [50, 51]. Risk factors for development of perinephric infection include nephrolithiasis, prior UTI, diabetes, immunocompromised state, and abnormal urinary tract. Despite modern medicine, the natural history and outcome of perinephric abscesses have not changed significantly. Overall, nephrectomy is performed in up to 20 % of patients and mortality approaches 15 % [51–53] in older series, with an absence of contemporary outcome data.

Diagnosis and Treatment

The traditionally poor outcome of perinephric abscesses has been partially attributed to significant delays in diagnosis. Most patients have prolonged symptoms, greater than 14 days. Common signs and symptoms include fever, abdominal pain, and dysuria. A review of 25 patients confirms these earlier reports [51]. Despite 40 % of patients having multiple predisposing conditions, only 33 % were correctly diagnosed as the time of hospitalization. The mean time to diagnosis after hospitalization was 3.4 days. Although plain abdominal radiography and IVU can provide information such as identification of stones, air, and urinary obstruction, these findings are nonspecific. Ultrasonography can show a sonolucent mass adjacent or displacing the kidney; nevertheless, the sensitivity may be as low as 64 % when compared to CT. Therefore, abdominal CT is the preferred imaging study when perinephric abscess is suspected. CT provides excellent anatomic details, with clear definition of the size and extent of the abscess and relationship to other organs (Fig. 8.5).

After identification of the perinephric abscess, treatment has typically consisted of parenteral antibiotics and drainage. In earlier reports, medical therapy was associated with high rates of mortality (65 %), likely due to delayed surgical intervention [53]. Thus, drainage of perinephric abscesses has been an important principle and an integral part of management. Advances in imaging techniques, combined with the ability to adequately drain abscesses percutaneously, have suggested that open surgical drainage and/or nephrectomy can be avoided. The decision is based on the size of the lesion and degree of illness. Small abscesses (<3 cm) generally resolve with antibiotic treatment alone. In our series, the 8 patients successfully managed with antibiotics had a mean abscess size of 1.8 cm, and all were less than 3 cm [51]. Conversely, 2 patients with unrecognized abscesses died despite intravenous antibiotics. Thus, the early identification of perinephric abscesses is crucial, and the decision to treat using antibiotics alone requires consideration of associated conditions and accurate staging of the abscess (Fig. 8.6). A retrospective review of 49 patients with abscesses ≤5 cm (mean 3.6 cm) treated with intravenous antibiotic alone demonstrated complete clinical regression in all patients. The time to radiographic resolution on CT ranged from 3 to 14 weeks, and the mean hospital stay was 15.3 days (range 5–31 days) [54].

Large abscesses (>5 cm) can be cured with antibiotics in conjunction with percutaneous catheter drainage. In 11 patients managed using this strategy, there was no mortality; however, longer hospitalization and prolonged catheter placement were necessary. Moreover, a third of patients ultimately required nephrectomy for persistent infection in the nonfunctional kidney. Thus, percutaneous drainage is likely safe and reasonable for most abscesses, including those larger than 3 cm, but one must realize that repeated or more aggressive intervention is often necessary. In addition, the perinephric abscess associated with poorly functioning kidney may benefit from early nephrectomy. The need for intervention is likely significantly higher than for renal abscesses. Coelho et al. found that surgical drainage, percutaneous drainage, or nephrectomy was required in 24 %, 42 %, and 24 % of patients with perinephric abscesses, while 69 % of renal abscesses required only medical treatment [43].

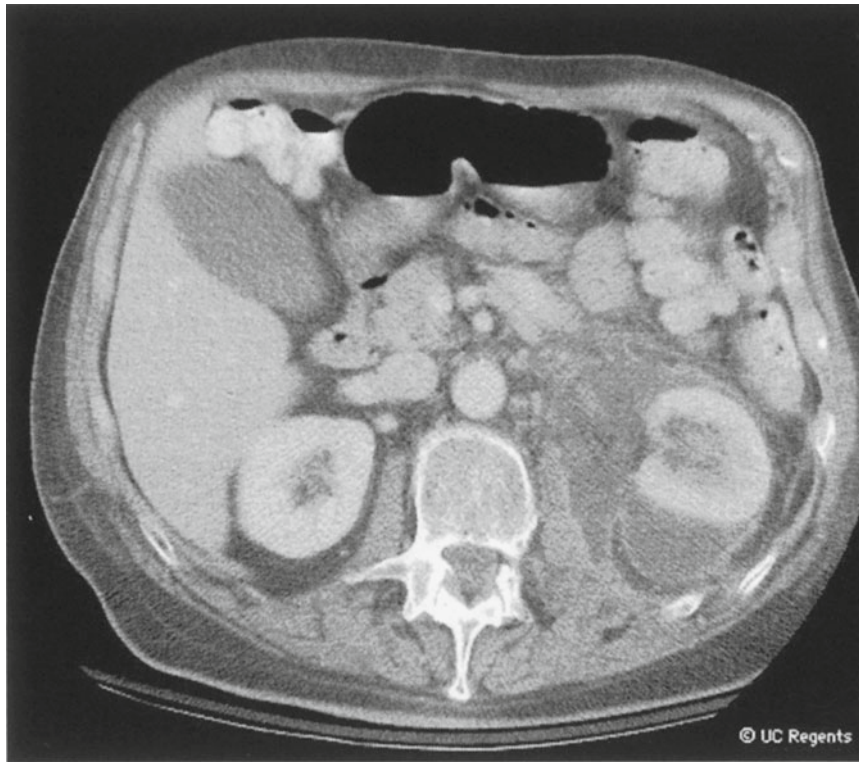

Fig. 8.5 CT demonstrating perinephric abscess around the left kidney. Note the pus surrounding the kidney, confined within Gerota' fascia, and normal appearance of the renal parenchyma

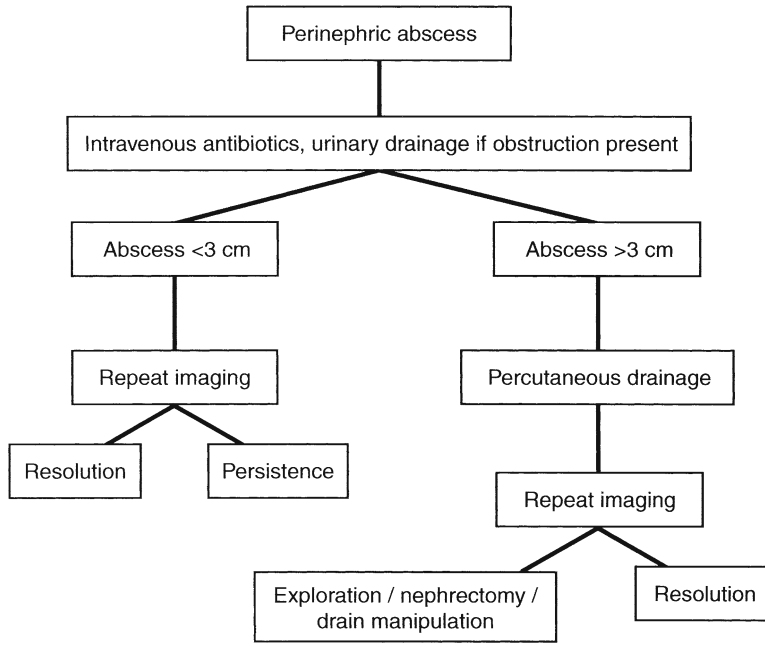

Fig. 8.6 Treatment algorithm for perinephric abscess

Pyonephrosis

Pyonephrosis describes a suppurative infection in a hydronephrotic renal unit. In many cases, it is associated with destruction of the kidney and minimal renal function. In general, patients are ill with sepsis syndrome or septic shock. The diagnosis is similar to acute pyelonephritis, although urinalysis and urine culture may not reveal bacteriuria if the system is completely obstructed.

Imaging and Treatment

Renal ultrasonography may show echogenic material within a dilated collecting system or a urine-debris level; in some cases, findings may be suggestive only for hydronephrosis. CT can also identify hydronephrosis and the level of obstruction; however, pyonephrosis may be indistinguishable from simple, uninfected hydronephrosis. Findings suggesting pyonephrosis include delayed nephrogram, fluid–fluid level, and gas within the collecting system. Retrograde pyelography can identify ureteral obstruction, filling defects from pus or stone, and permit collection of material for culture.

The obstructed and infected urinary system requires prompt drainage and antibiotic therapy. Options include ureteral stenting and percutaneous nephrostomy tube placement. In stable patients with anatomy amenable to retrograde instrumentation, cystoscopy and ureteral stent placement are indicated. In extremely ill patients, a percutaneous approach may be the most rapid means of renal decompression. Watson et al. reported excellent outcome in 315 patients requiring percutaneous nephrostomy drainage for pyonephrosis [55]. Direct renal access provided not only effective drainage but also additional information regarding uropathogens in 37 %. Subsequently, after resolution of the acute infection, definitive management of the cause of obstruction can be performed.

Emphysematous Pyelonephritis

Emphysematous pyelonephritis is a potentially life-threatening necrotizing infection of the renal parenchyma [56]. Historically, management has involved aggressive surgical intervention due to the severity of infection and significant mortality. Similar to perinephric abscesses, however, there has been a significant shift in the modern management paradigm.

Pathophysiology

The acute necrotizing nature of emphysematous pyelonephritis results from the synergism of gas-forming bacteria, high tissue glucose, poor tissue perfusion, and host susceptibility (diabetes, urinary obstruction) [57]. Bacterial pathogens resulting in gas formation include mixed acid fermentation by Enterobacteriaceae (e.g., *E. coli*, *K. Pneumoniae*, *Proteus*) and butyric fermentation (*Clostridium*). The primary components of the gas are H_2 and CO_2; trace amounts of ammonia and methane may be detected.

Diagnosis and Treatment

Adults are exclusively at risk for emphysematous pyelonephritis, with women affected more often than men. Signs and symptoms are consistent with acute pyelonephritis which precedes frank necrosis, but do not improve despite antibiotics. The finding of intraparenchymal gas is pathognomonic for emphysematous pyelonephritis; this produces a mottled shadow overlying the kidney as well as crescent configuration around the renal contour. Plain abdominal radiography, IVU, or ultrasonography can detect parenchymal gas. This should be distinguished from air within the collecting system, which is a less serious condition responsive to antibiotics alone. CT provides details regarding the gas pattern and anatomic extent of infection (Fig. 8.7). Several authors have proposed classification schemes for

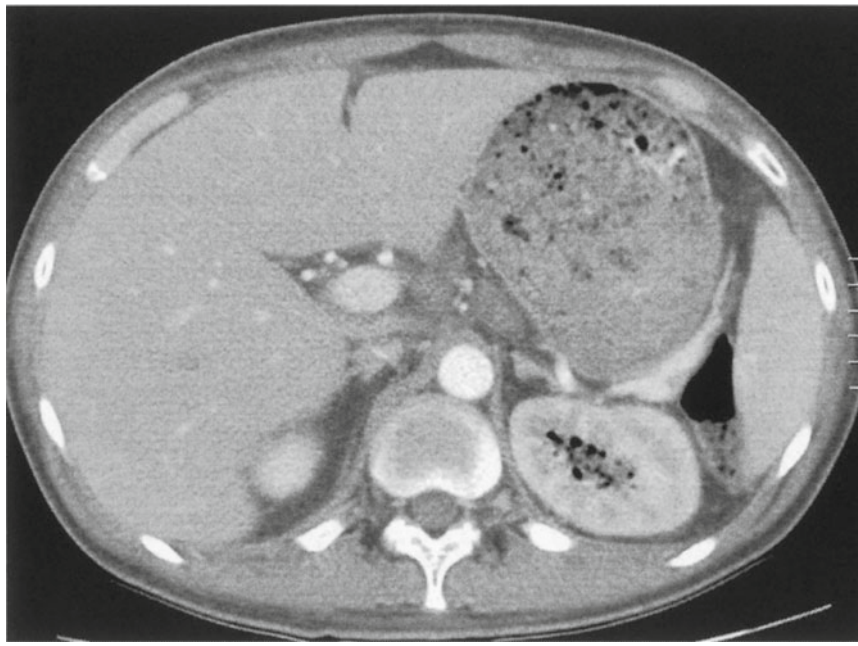

Fig. 8.7 CT demonstrating gas within the left kidney. This diabetic patient had evidence of fungal pyelonephritis

Table 8.5 Classification systems for emphysematous pyelonephritis

	Characteristics
Stage	
I	Gas within parenchyma or perinephric tissue
II	Gas in kidney and surroundings
III	Extension of gas through Gerota's fascia
	Bilateral involvement
Class	
1	Emphysematous pyelitis
2	Parenchymal gas confined to kidney
3A	Extension of gas or abscess to perinephric area
3B	Extension to pararenal space
4	Bilateral involvement or infection of solitary

emphysematous pyelonephritis, based on extent of infection and gas (Table 8.5) [58, 59].

No uniform management strategy exists for emphysematous pyelonephritis. In addition to antibiotics and supportive care, relief of urinary obstruction in the affected kidney is indicated if present. Conservative management, with antibiotics alone or in conjunction with percutaneous catheter drainage, is increasingly utilized with good outcomes [57, 59, 60]. Accurate assessment of the extent and nature of infection is vital to the decision process. Huang et al. proposed that localized (class 1 and 2) infections can be treated with percutaneous drainage; this approach is also feasible for more extensive (class 3 and 4) cases without systemic manifestations. Fulminant infection may be best managed with immediate nephrectomy. Best et al. reported complete resolution of infection in 5 patients with antibiotics alone; however, they differentiate between gas-forming renal abscess characterized by large gas lesion, as in their series, from true diffuse necritizing infection with multiple small bubbles [60]. Surgical drainage or nephrectomy is indicated if the infection persists or progresses.

Xanthogranulomatous Pyelonephritis

Xanthogranulomatous pyelonephritis (XGP) is the end-result of severe, chronic infection of the kidney. It is relatively uncommon (0.6–1.4 % of renal inflammation evaluated pathologically) but typically is unilateral and develops in the presence of urinary obstruction and nephrolithiasis [61, 62]. In cases of nephrectomy performed for pyelonephritis, the finding of XGP is more common (19 %) [63].

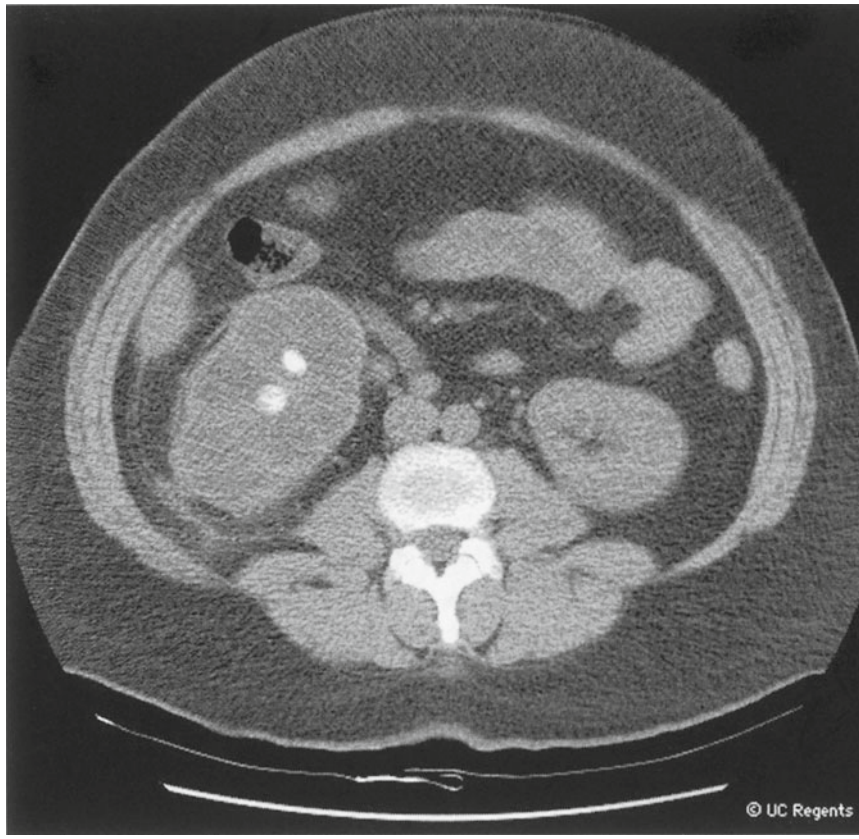

Fig. 8.8 Non-contrast CT in a patient with right xanthogranulomatous pyelonephritis. Note the calcifications, enlarged renal form, and areas of reduced attenuation, potentially representing pus, dilated calyces, or inflammatory tissue

Pathogenesis

The combination of urinary obstruction, nephrolithiasis, and UTI are important elements in the development of XGP [64]. Nephrolithiasis is noted in nearly 90 % of patients, with many having staghorn calculi [63]. Infection is usually secondary to either *E. coli* or *P. mirabilis*; other uropathogens include *Klebsiella*, *Pseudomonas*, and *Enterobacter*. Progressive destruction of the renal parenchyma occurs, with resulting impairment in renal function. Histologically, XGP is characterized by sheets of lipid-laden macrophages (xanthoma cells) around abscesses within the parenchyma, admixed with lymphocytes, giant cells, and plasma cells. The kidney grossly is enlarged with destruction and replacement of the parenchyma by yellow nodules and pericalyceal granulation.

Diagnosis and Treatment

Most patients present with typical evidence of upper UTI—flank pain, fever, and bacteriuria. Although the diagnosis of XGP relies on a pathologic diagnosis, some have suggested that urinary cytology can accurately predict XGP in 80 % of cases [65]. Nevertheless, XGP can be suggested clinically by the combination of enlarged kidney, presence of renal calculi, and poorly functioning kidney [66]. IVU may detect all of these features, although with less sensitivity than CT. Ultrasound can be useful in noting renal enlargement, stones, and multiple hypoechoic foci corresponding to xanthoma granulomas.

CT is the preferred modality in the evaluation of XGP (Figs. 8.8 and 8.9). Characteristic features include a large, reniform mass with

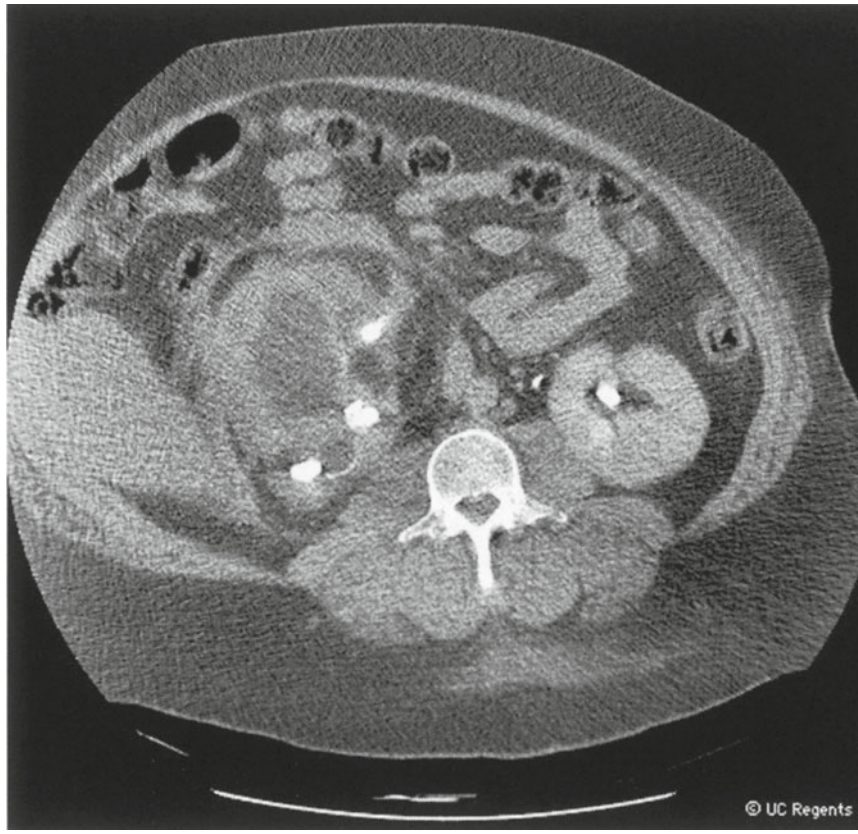

Fig. 8.9 Delayed CT demonstrating right xanthogranulomatous pyelonephritis. Note the multiple calcifications as well as nearly absent renal parenchyma and evidence of inflammation within Gerota' fascia

poor function. Non-enhanced images demonstrate a central calcification typically without pelvic dilation. The renal parenchyma is usually thin and contains multiple round hypodense masses representing dilated calyces, abscesses, or inflammatory tissue. CT also depicts the degree of perinephric and pararenal involvement, with frequent extension into the psoas, back, or abdominal wall muscles. Cutaneous and renocolic fistulae may be visualized, as well as reactive lymphadenopathy. Precise identification of these features is important for planning surgical intervention.

The appropriate management of XGP is often unclear, given the diagnostic uncertainty in many cases. The radiographic appearance may mimic other renal diseases, including malakoplakia, lymphoma, urothelial carcinoma, and renal cell carcinoma. Antimicrobial therapy should be initiated, and long-term treatment can eradicate the infection. If symptoms or UTI persists, or if underlying malignancy cannot be excluded, then nephrectomy is warranted. An attempt should be made to completely excise the kidney and surrounding inflammatory tissue; these operations are often challenging and associated with significant morbidity. Only recently have reports documented the utility of laparoscopy in removing XGP kidneys, with moderate success and limited complications [67]. A series of 26 patients undergoing nephrectomy for XGP found that advantages of laparoscopy compared with open surgery included less blood loss and reduced need for transfusion as well as short hospital stay [68]. Conversion to an open procedure was required in 7 % and complication rates were comparable for the two approaches.

Summary

Infection of the upper urinary tract is relatively common and associated with potentially serious sequelae. Both uncomplicated pyelonephritis and purulent renal infections can be difficult to diagnose and require a high index of suspicion. Accurate identification of the causative organism allows the tailored use of antibiotic therapy, and careful follow-up and subsequent specimen culture help ensure adequate treatment of the infection.

Utilization of radiographic studies, primarily computed tomography, is warranted when the clinical picture is either unclear or deteriorates. Aggressive resuscitation and management may be necessary when systemic manifestation or sepsis results. The early identification of more severe complications of renal infection is crucial for prompt intervention, which is indicated by the severity of infection and size of abscess. The evolution of minimally invasive techniques of abscess (renal and perinephric) drainage has reduced patient morbidity; however, inadequate drainage may result in significant morbidity and mortality and open surgical drainage and/or nephrectomy may still be required.

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Genital and Infectious Emergencies: Prostatitis, Urethritis, and Epididymo-orchitis

9

Hunter Wessells

Introduction

The management of acute genitourinary tract infections continues to evolve as a result of advances in diagnostic testing, emerging antibiotic resistance, and the absence of new antimicrobial agents. Whereas in the past the ability to recognize and treat lower urinary tract and genital infections required diagnostic acumen based on physical findings and microscopic evaluation of urethral swab specimens, sophisticated molecular and radiologic tests allow rapid identification and treatment of acute prostatitis, urethritis, and epididymo-orchitis. These entities usually involve common pathogenic organisms and high-risk patient populations, and many are sexually transmitted diseases (STD). However, each disease entity has a distinct pathology necessitating individual evaluation and management. This chapter limits its scope to acute bacterial infections of the prostate, urethra, and male reproductive organs.

Acute Bacterial Prostatitis

Definition and presentation. The National Institute of Diabetes and Digestive and Kidney Diseases classification system for prostatitis syndromes designates acute bacterial prostatitis (acute infection of the prostate) as Category I [1]. The remaining chronic bacterial, chronic nonbacterial, and asymptomatic prostatitis are classified as Category II, III, and IV, respectively. Acute prostatitis is rare and accounts for less than 5 % of all prostatitis syndromes [2].

Acute prostatitis is characterized by rapid onset of fever, chills, low back, perineal/rectal pain, urinary frequency, urgency, nocturia, hesitancy, or sensation of incomplete bladder emptying [3]. Generalized symptoms, such as malaise, arthralgia, and myalgia, may also accompany urologic symptoms. Past medical history may be significant for a prior history of urinary tract infection, indwelling or intermittent urethral catheterization, urethral instrumentation, recent prostate needle biopsy, diabetes, chronic renal insufficiency, and other immunocompromised states.

Physical examination. Patients typically have elevation in temperature and appear clinically ill. The abdominal examination may reveal bladder distension and the genitalia may show an associated urethritis or epididymitis. An exquisitely tender swollen prostate gland is pathognomonic. The consistency of the gland has been described as boggy, irregular, partially or totally firm, or warm to the touch. Aggressive rectal examination or massage is not recommended due to the risk of severe pain and/or bacteremia [4].

Laboratory. Urinalysis is almost invariably abnormal with acute prostatitis. Bacteriuria, pyuria, and

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hematuria are common. The midstream urine should be cultured and antibiotic sensitivity should be tested. Other laboratory studies may be indicated including complete blood count with differential, blood cultures (if the patient is febrile), and chemistry studies. *In men with suspected STD-related prostatitis, urine should also be sent for additional nucleic acid amplification testing to identify chlamydial and gonococcal organisms.*

Microbiology. Microbial pathogens associated with acute prostatitis and prostatic abscess include *E. coli*, other *Enterobacteriaceae*, *Staphylococcus*, *Enterococcus*, *Neisseria gonorrhoea*, and *Chlamydia trachomatis* [3].

Treatment. Acute bacterial prostatitis (NIH Category I) should be treated promptly with oral fluoroquinolones or sulfonamides. For severe symptoms and signs, including fever and chills, leukocytosis and hemodynamic alterations, patients should be hospitalized and treated with parenteral antibiotics. Recommended doses of fluoroquinolones are ciprofloxacin 500 mg BID or levofloxacin 500–750 mg QD. Alternatively, acute prostatitis can be treated with oral trimethoprim-sulfamethoxazole (160 mg TMP and 800 mg SMX). With associated urosepsis, intravenous antibiotics are indicated (ampicillin 2 g intravenously every 6 h and gentamicin 5 mg/kg every 24 h) [2]. From the results of susceptibility testing from urine culture, appropriate changes in antimicrobial therapy should be made. Incomplete patient response may indicate the need to alter antibiotic therapy or investigate the presence of prostatic abscess. Oral therapy should be continued for a total of at least 4 weeks after the diagnosis of acute bacterial prostatitis to prevent the development of chronic bacterial prostatitis [5]. Additional general supportive measures include hydration, analgesics, stool softeners, antipyretics, and bed rest [5].

Related urologic problems. Acute urinary retention due to acute prostatitis (or prostatic abscess) traditionally has been managed with suprapubic cystostomy tube placement. Although anecdotal complications related to urethral catheterization have been reported [6], no prospective studies or large case series have shown a clear relationship between transurethral catheterization and worse outcomes of acute bacterial prostatitis. Thus catheter drainage per urethra has gained acceptance.

Prostatic Abscess

Presentation. Prostatic abscess may be evident at the time of presentation of a patient with acute prostatitis. It may also develop after a course of oral antimicrobial therapy and have a more indolent presentation. Clinical signs of prostatic abscess are variable and include urinary retention, fever, dysuria, frequency, and perineal pain. Presentations can be similar to those of acute prostatitis. Tenderness and fluctuance are unreliable indicators [7]. Patients with diabetes mellitus and acute prostatitis signs/symptoms are predisposed to prostatic abscess formation [8].

Radiologic evaluation. Axial imaging with computed tomography is important to the prompt and accurate diagnosis of prostatic abscess (Fig. 9.1). Transrectal ultrasonography also may be useful for abscess fluid aspiration (perineally or transrectally) for diagnostic and/or therapeutic purposes.

Treatment. Urgent urologic consultation is imperative to ensure prompt drainage of the abscess. In combination with appropriate antimicrobial therapy, incision and drainage will lead to the resolution of most prostatic abscesses. Transurethral, perineal, and transrectal drainage of prostatic abscesses have been described [9–12]. Ultrasound guided transurethral incision or resection (see Fig. 9.2) is now most the common treatment strategy for prostatic abscess [10, 13].

Urethritis

Presentation. Acute urethritis in the male is commonly due to STD (gonococcal and/or chlamydial) and rarely due to *Mycoplasma genitalium*, *Ureaplasma ureolyticum*, or *Trichomonas vaginalis* [14, 15]. Classic gonococcal urethritis produces a profuse, purulent urethral discharge with dysuria. Although gonococcal urethritis can present with scant or absent discharge, this scenario is

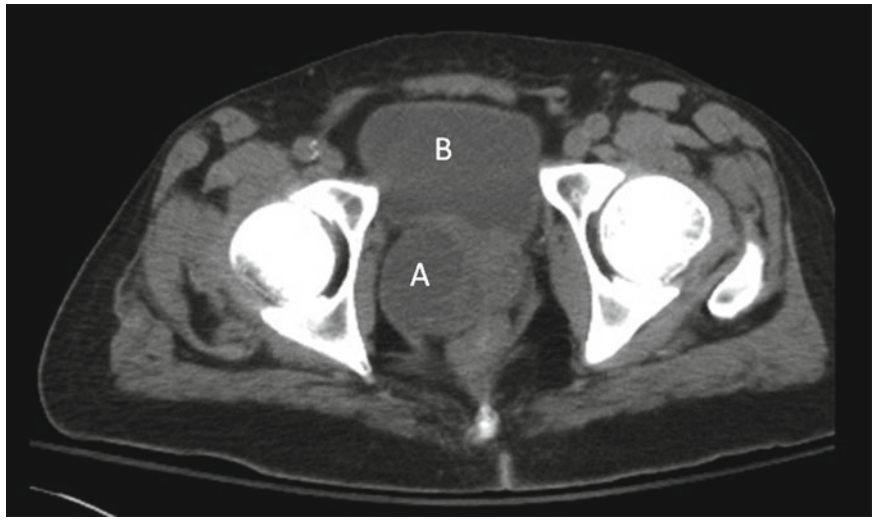

Fig. 9.1 CT scan of prostatic abscess demonstrating large low density collection within right side of the prostate (A) distinct from the low density of the urinary bladder (B)

more likely to occur with nongonoccal urethritis (NGU). In all cases, laboratory diagnosis is essential for accurate diagnosis.

Microbiology. *Neisseria gonorrhoea* (most common cause of urethritis) has an incubation period of 1–9 days. *Chlamydia trachomatis* is responsible for most cases of NGU in the male and has an incubation period of 7–21 days. Coinfection with gonococcal organisms is found in up to 40 % of patients with *C. trachomatis* [16].

Diagnostic testing. Clinic-based diagnostic tools such as Gram-stain microscopy and first void urine microscopy can help establish evidence of urethral inflammation. A urethral specimen collected with a calcium alginate urethro-genital swab is preferred for inoculation of culture medium and gram staining. The gram stain remains highly sensitive and specific for *N. gonorrhoeae* [17] (gram-negative intracellular diplococci) but not for *C. trachomatis*. Urethral inflammation, as determined by a gram stain from a urethral swab specimen, in the absence of *N. gonorrhoeae*, is suggestive of NGU [18]. Standard cell culture techniques remain sensitive and specific for gonococcal and chlamydial urethritis [17, 19]. Nucleic acid amplification testing (NAAT) of both *N. gonorrhoeae* and *C. trachomatis* may identify additional infections, either through urethral or urine specimens. These assays enhance the specificity and sensitivity of testing for *C. trachomatis*, especially when the high coinfection rate with *N. gonorrhoeae* is considered [20].

Treatment. Recommended treatments of gonococcal and NGU in men are listed in Tables 9.1 and 9.2 based on data from the Centers for Disease Control and Prevention. Single dose regimens improve compliance, especially if dispensed on site; the first dose can be directly observed.

For *N. gonorrhoeae*, resistance to antimicrobial therapy complicates treatment. Thus, fluoroquinolones are no longer recommended in the US for the treatment of gonorrhea. Furthermore, the frequent coinfection of *N. gonorrhoeae* and *C. trachomatis* now indicate the routine cotreatment with both a cephalosporin *and* azithromycin or doxycycline. For definitive chlamydial infection without gonococcal coinfection, treatment consists of azithromycin or doxycycline. Persistent urethritis after doxycycline treatment may be the result of *Mycoplasma genitalium*, *Ureaplasma ureolyticum*, or *Trichomonas vaginalis*.

Sexual partners (within the preceding 60 days) of patients infected with *N. gonorrhoea* or *C. trachomatis* should be referred for evaluation, testing, and empiric treatment on the

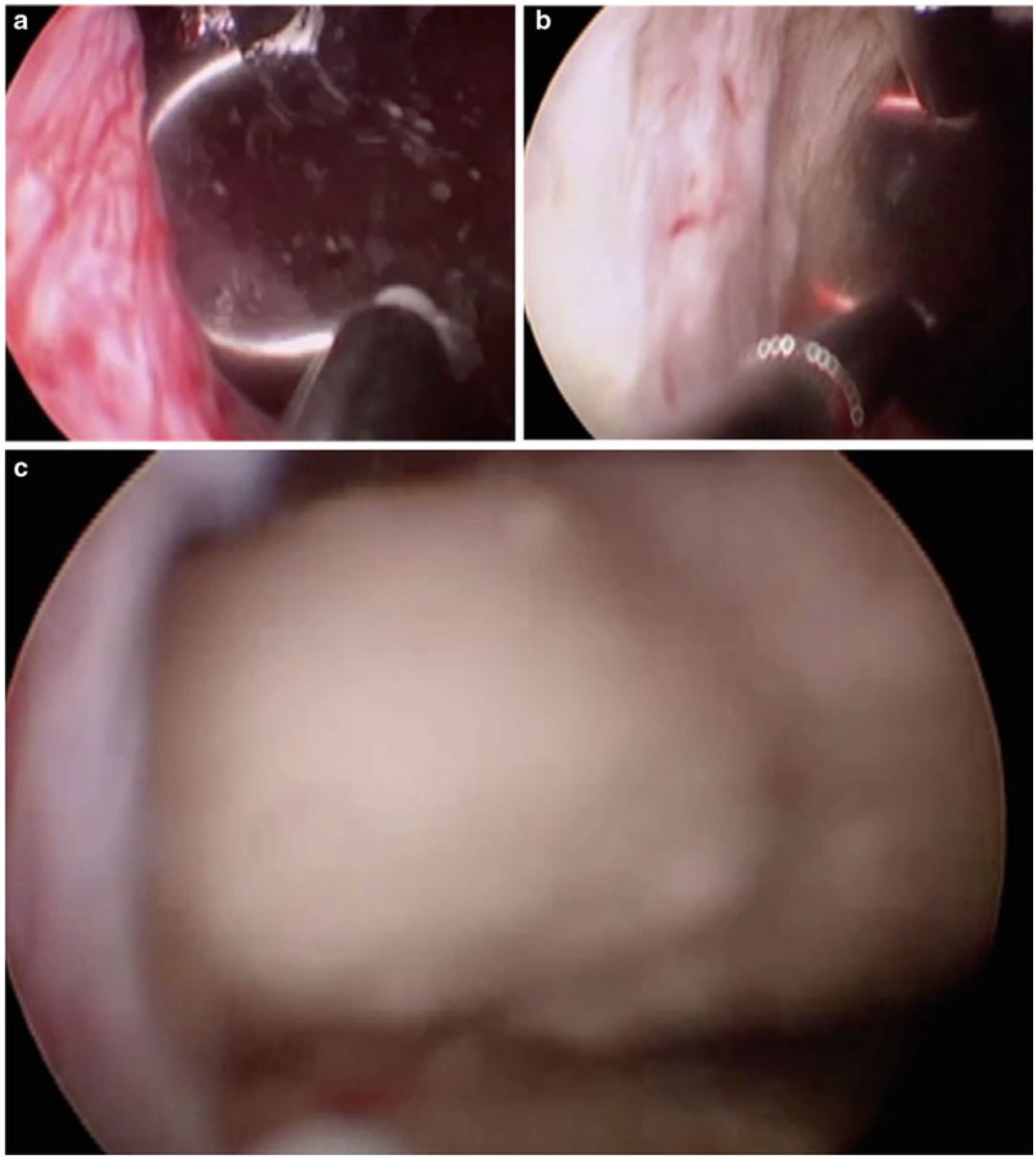

Fig. 9.2 Endoscopic images of transurethral drainage of the prostatic abscess shown in Fig. 9.1. (**a**) Right lobe of prostate before drainage. (**b**) Transurethral resection of portion of right lobe, before unroofing. (**c**) Purulent drainage into the prostatic fossa

basis of contact [21]. Men treated for NGU should abstain from sexual intercourse for 7 days after single dose therapy or until completion of a 7 day regimen. This minimizes transmission or reinfection. Finally, all persons diagnosed with a new STD require testing for syphilis and HIV.

Epididymitis and Orchitis

Etiology. The causes of epididymo-orchitis reflect common causes of genitourinary infection in males based on particular age groups. In children and older men (>35 years), the most common cause of epididymitis is coliform organisms

Table 9.1 Treatment of patients with uncomplicated gonococcal infections of the urethra

Recommended regimens	
Ceftriaxone	250 mg IM in a single dose
OR, IF NOT AN OPTION	
Cefixime	400 mg orally in a single dose
OR	
Single dose injectable *cephalosporin* regimens	
PLUS	
Azithromycin	1 g orally in a single dose
OR	
Doxycycline	100 mg orally twice a day for 7 days

Adapted from Centers for Disease Control and Prevention [Sexually Transmitted Diseases Treatment Guidelines, 2010]. MMWR 2010;59(No. RR-5912):[1–116]

Table 9.2 Treatment of patients with nongonococcal urethritis

Recommended regimens	
Azithromycin	1 g orally in a single dose
OR	
Doxycycline	100 mg orally twice a day for 7 days
Alternative regimens	
Erythromycin base	500 mg orally 4 times a day for 7 days
OR	
Erythromycin ethylsuccinate	800 mg orally 4 times a day for 7 days
OR	
Levofloxacin	500 mg orally once daily for 7 days
OR	
Ofloxacin	300 mg orally twice a day for 7 days

Adapted from Centers for Disease Control and Prevention [Sexually Transmitted Diseases Treatment Guidelines, 2010]. MMWR 2010;59(No. RR-5912):[1-116]

resulting in bacteriuria. In contrast, the organisms causing urethritis or STD are the common etiologies of epididymitis and orchitis in young adult men (<35 years) [22].

Presentation and differential diagnoses. The clinical syndrome of acute epididymitis (or epididymo-orchitis) results from infection and inflammation of the epididymis and/or testis. It is usually caused by the ascending spread of infection from the urethra or bladder and characterized by progressive increase in pain and swelling of one epididymis and/or testis. It may be associated with fever, lower urinary tract symptoms, and the sensation of a mass in the scrotum [23]. Pertinent information from the history of present illness includes: duration, acuity of onset, location, radiation, associated symptoms, and ameliorating factors. These factors may help to distinguish between epididymo-orchitis and testicular torsion. Epididymo-orchitis usually has a 2–3 day period of progressive increase in scrotal discomfort before severe pain is noted. The pain is localized to the scrotum and does not radiate. Nausea and vomiting are absent. In contrast, testicular torsion has a very acute onset with pain in the testicle possibly radiating into the lower abdominal quadrants. It is usually associated with anorexia, nausea, and/or vomiting.

The past medical history of a patient with epididymo-orchitis may be entirely unremarkable or indicate conditions predisposing to chronic bacteriuria with coliform organisms. These conditions include: congenital urological anomalies (hypospadias, neurogenic bladder, ectopic ureteroceles), practice of anal intercourse, choice of sexual partner (men having sex with men), and acquired obstructive urinary diseases (BPH, prostate cancer, urethral strictures) in older men [24–26].

Physical examination. The physical exam should be focused to differentiate epididymo-orchitis from other urologic and nonurologic conditions. Vital signs are usually normal, but if the temperature is elevated in the patient with epididymitis, a severe infection or associated abscess should be suspected. The abdomen is examined to exclude other intra-abdominal processes (renal colic, appendicitis, hernia) causing radiation to the groin. The penis and urethral meatus are inspected for signs of urethritis, and the scrotum is carefully examined with the patient in the supine position. The overlying scrotal skin is inspected for erythema, fixation, or fluctuance indicating abscess. The palpation of scrotal contents is directed first to the contralateral uninvolved side and subsequently to the affected side. The presence of an ipsilateral cremasteric reflex is a useful adjunctive sign suggesting epididymis rather than torsion [27]. Within the epididymis, the head

or tail may be enlarged and tender with or without involvement of the testis and/or surrounding structures. The position of the testis may be helpful in differentiating torsion and infection. Epididymo-orchitis is associated with a normal vertical orientation of the testis and relief of pain with scrotal elevation (Prehn's sign). Torsion may be associated with a high horizontal lie of testis. However, this sign is not uniformly present. With epididymitis, the spermatic cord may be tender and swollen possibly extending into the groin. Importantly, the prostate should be examined to exclude concurrent prostatitis.

Diagnostic testing. Urinalysis or urethral smear can usually determine the microbial cause of epididymitis [23]. For suspected cases of STD (especially in men younger than 35 years), gram stain of the urethral smear is advisable along with subsequent NAAT. A midstream urine specimen should be performed in all patients and examined for the presence of gram-negative bacteria. In less obvious cases of testicular pain without clear evidence of abnormalities on physical exam, the presence of blood on urinalysis should raise the possibility of renal colic, masquerading as torsion or epididymitis, with radiation of pain to the scrotum.

Microbiology. In men under 35 years of age, the most common bacteria causing epididymo-orchitis are STD organisms. The percentage of men in this age group with *E. coli* infection ranges from 0 to 24 %, most commonly due to anal intercourse [25]. In men over the age of 35, the majority of pathogenic bacteria are due to *E. coli*, although STD organisms may still cause a substantial amount of epididymo-orchitis [22]. Other rare pathogenic bacteria include *Haemophilus influenzae* [28]. Rare systemic infections causing epididymitis include: tuberculosis, atypical microbacteria, cryptococcus, brucellosis, and schistosomiasis [29–31].

Radiologic evaluation. Color-duplex scrotal ultrasonography can help to visualize the epididymis, testis, and surrounding tissues and distinguish epididymitis from torsion [32]. Sonographic features of acute epididymitis include enlargement of the epididymis and a primarily inhomogeneous echogenic texture (Fig. 9.3). Echogenic areas within the swollen epididymis and a reactive hydrocoele may be present. Usually the visualized testis is normal, although with orchitis the testis may have increased blood flow with color Doppler (Fig. 9.4) or a diffusely abnormal echogenicity with no residual normal tissue. A helpful finding in inflammation of the scrotal contents is thickening of the superficial skin overlying the testis or epididymis, useful in differentiating a very extensive orchitis from neoplasm. Diffuse inflam-mation of the testis usually causes mild to moderate enlargement with preservation of the normal oval shape and smooth contour of the testis. Focal inflammation of the epididymis can also be delineated on ultrasonography. A localized lesion (enlarged and hypoechoic or with mixed echogenicity) may be compared with the normal contralateral epididymitis. Focal orchitis may show localized areas of decreased echogenicity secondary to the close proximity of the inflamed epididymis [33].

Associated testicular infarction. Testicular infarction (due to compromise of testicular blood flow from edema and a compartment-like syndrome) may occur secondary to epididymo-orchitis [34–36]. The infarction secondary to acute inflammation may be difficult to differentiate from torsion and requires exploration and orchiectomy [37].

Associated abscess. Abscesses of the epididymis, testis, or scrotum related to acute bacterial or mycobacterial infection are easily detected on ultrasonography. Focal hypoechoic or anechoic regions in the epididymis or testis with involvement of the overlying scrotal soft tissue and skin can usually be differentiated from simple reactive hydroceles (Fig. 9.5).

Treatment. Appropriate antimicrobial therapy for acute epididymitis is based on history, physical examination, and findings from urinalysis and/or urethral smear. Therapy should be instituted empirically and follow-up adjustment based on culture and sensitivities are indicated. For mild to moderate epididymo-orchitis due to bacteriuria, a

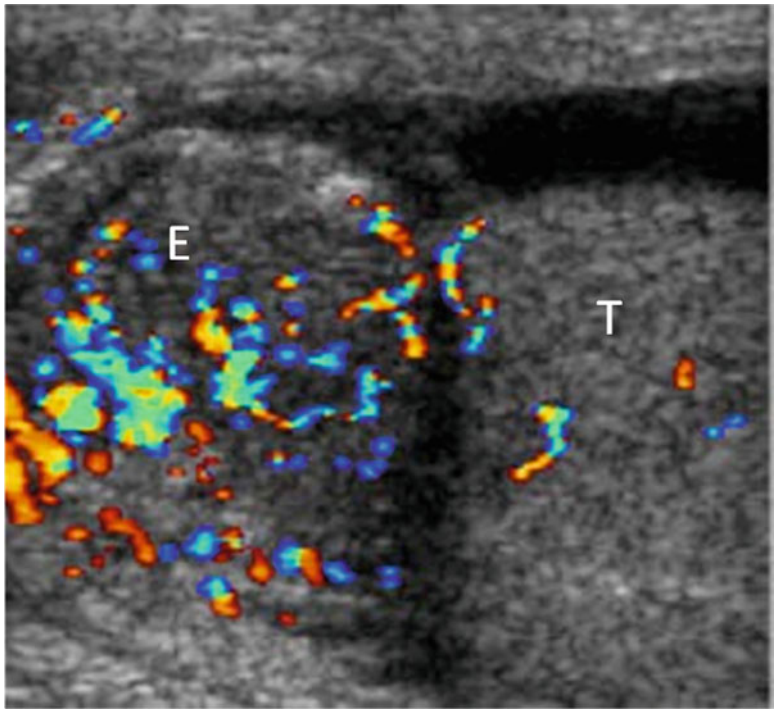

Fig. 9.3 Ultrasonographic appearance of acute epididymitis. Note that the epididymis (left-sided structure demonstrating increased color flow on Doppler) is equal in size to the adjacent testis (photograph courtesy of T. Dubinsky, M.D.)

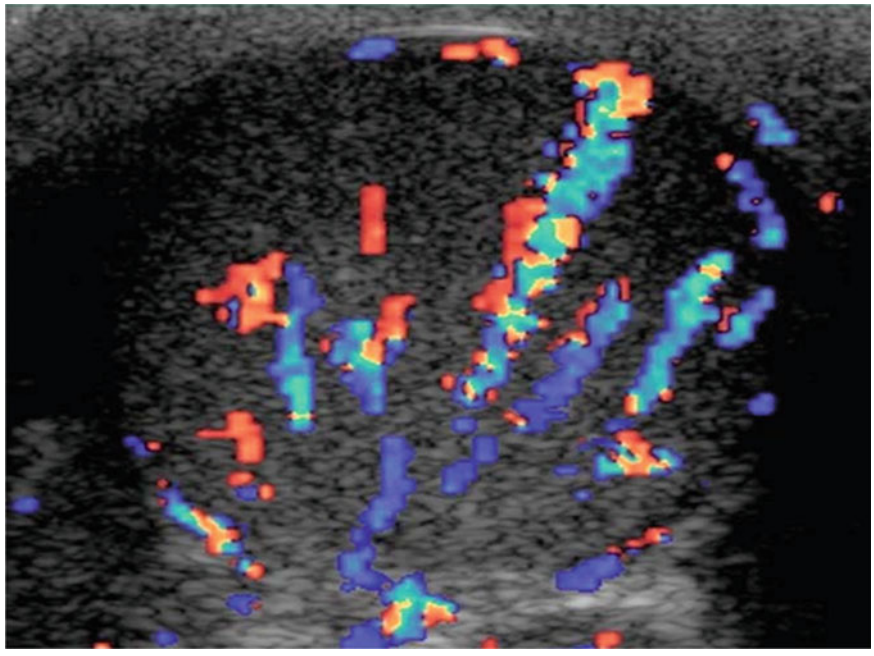

Fig. 9.4 Orchitis. The testis in enlarged and has increased blood flow visible on color Doppler scanning (photograph courtesy of T. Dubinsky, M.D.)

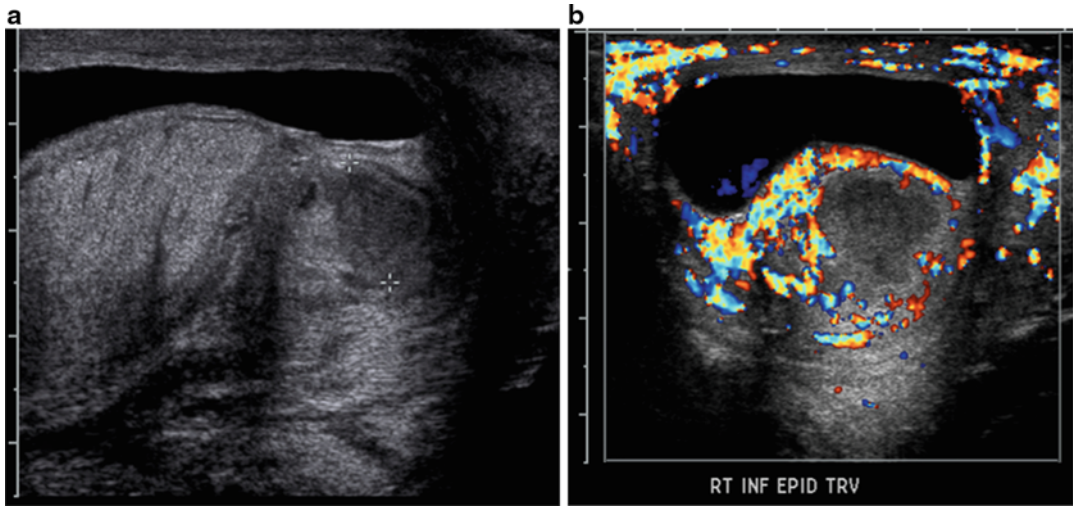

Fig. 9.5 (**a**, **b**) Epididymitis with abscess formation. Note reactive hydrocele (dark anechoic fluid) and low density collection within epididymis

10-day course of broad-spectrum fluoroquinolone antibiotic, such as levofloxacin 500 mg orally daily, is recommended. In severe epididymo-orchitis associated with systemic illness, a combination of intravenous beta-lactam and aminoglycoside antibiotics is indicated. For epididymo-orchitis due to STD organisms, treatment should include single dose therapy to cover *N. gonorrhea* and a longer course of therapy for nongonococcal urethritis. Thus the recommended regimen includes ceftriaxone 250 mg IM in a single dose plus doxycycline 100 mg orally twice a day for 10 days. In all cases of acute epididymo-orchitis, supportive measures including bed rest, scrotal elevation, nonsteroidal anti-inflammatory drugs, and/or local anesthetic spermatic cord block may be helpful [23].

Indications for scrotal exploration, *drainage of abscess*, *and/or orchiectomy*. Antibiotic therapy and supportive measures will allow most cases of epididymo-orchitis to resolve without need for surgical intervention. However, scrotal exploration/drainage or orchiectomy is indicated for abscesses or an infarcted testis secondary to severe infection, respectively. The ultrasonographic presence of fluid adjacent to the testis does not necessitate incision and drainage in all cases. Systemic illness, obvious fluctuance, significant inflammatory changes of the scrotum, spermatic cord, or perineum, or obvious abscess formation with echogenic material indicate the need for scrotal exploration and drainage. A decision regarding orchiectomy can be difficult. However, in many cases, the testis will be extensively involved in inflammatory and infectious processes and requires removal. Abscesses arising solely from an acutely inflamed and infected epididymis may be drained and debrided without the need for orchiectomy. If exploration and drainage is not elected, hospitalization with broad-spectrum intravenous antibiotics, frequent physical examination, and repeat imaging of the scrotum and testicle is advised.

Conclusions

The persistence of unprotected sexual exposures in the United States and other developed and developing countries indicates the continued need to identify and treat prostatitis, urethritis, and epididymitis. Nucleic acid amplification testing and high resolution scrotal ultrasonography are important adjuncts to accurate diagnosis and treatment. For men with prostatitis, the diagnosis rests on accurate history and detailed physical examination. Appropriate use of antimicrobial agents is critical in order to avoid progressively increasing rates of bacterial resistance.

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Penile Prosthesis Infection

10

Natalya A. Lopushnyan and Thomas J. Walsh

Introduction

Erectile dysfunction (ED) is a major health concern for aging men. Epidemiologic studies estimate that greater than 50 % of males ages 40–70 years old will suffer from ED of varying severity with the prevalence of complete ED tripling from 5 to 15 % between ages 40 and 70 [1]. For men with severe, medically refractory ED, penile prosthesis implantation remains a mainstay of treatment, and it is estimated that approximately 15,000–20,000 penile prostheses are placed annually in the United States [2, 3].

Penile prosthesis infection is infrequent, but remains one of the most feared complications. Depending on the severity of the infection, it may become a urologic emergency and frequently results in the removal of the device with a high degree of patient morbidity. If immediate prosthesis revision, or "salvage" surgery is performed, it carries a greater risk of intra- and postoperative complications than the original procedure and possibly decreased patient satisfaction [4, 5]. Urologists must be familiar with the assessment and management of penile prosthesis infection.

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Infection Risk

Since its introduction by Scott nearly 40 years ago, the inflatable penile prosthesis (IPP) has become the most frequently placed type of penile implant [6]. Improvements in design have allowed for longer device survival and as a result, infection is one of the leading causes of the penile prosthesis failure. Among men undergoing first time penile prosthesis implantation, 1–3 % will experience infection. Among those who undergo revision surgery, the risk is significantly higher with as many as 18 % experiencing infection [7, 8].

Pathophysiology and Pathogenic Organisms

The most common source of penile prosthesis infections are organisms introduced from the skin at the time of implant surgery, although bacterial seeding from another body site such as dental manipulation has been reported [9]. The most common pathogenic organism is *Staphylococcus epidermidis*, an organism of low virulence which may colonize up to 70 % of IPPs even without clinically evident infection [10]. More aggressive infections have been reported with *Pseudomonas aeruginosa*, methicillin-resistant *Staphylococcus aureus*, *Serratia marcescens*, *Enterococcus faecalis*, and *Proteus mirabilis* [11]. Infection of the decommissioned reservoir following IPP

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revision surgery with *Actinomyces neuii* has also been reported [12]. Infections caused by yeast, fungi, or anaerobic bacteria are uncommon. Necrotizing infections following penile prosthesis implantation are extremely rare and mostly limited to the case reports and small series with *Bacteroides* species as the implicated pathogenic organism [13–15].

Among IPPs at the time of revision surgery without clinical evidence of infection, evidence suggests that bacteria may survive due to the biofilm formation [10]. Staphylococcal contamination likely occurs at the time of penile prosthesis insertion with production and growth of the biofilm [16]. Once protected in the biofilm, bacteria can survive at a markedly reduced metabolic rate. Biofilm is a combination of bacterial colonies and exopolysaccharide matrix adherent to the surface of the prosthetic material or any other inert surface. Biofilm acts as a protective environment against host defenses and antimicrobial agents [17] and integrated bacteria can withstand an antibiotic concentration of 1,000–1,500 times higher than the concentration necessary to kill free-floating bacteria of the same species [18]. Clinical symptoms are caused when bacteria are released from the biofilm to become free floating (planktonic). Antibacterial agents can kill the planktonic bacteria, but they are unable to eradicate those within the biofilm [19].

Risk Factors

A variety of factors increase the occurrence of penile prosthesis infections. Revision surgery for a mechanically malfunctioned device carries a significantly higher infection rate. As reported by Jarow in 1996 infection with IPP insertion was 1.8 % after primary procedure, 13.3 % after revision, and 21.7 % for the patients requiring reconstruction of the corpora. Operative time was significantly longer for the reconstructive patients, 255 min compared with 98 for primary procedure [20]. Decrease in both surgical time and complication rate (including infection) has been shown among *center of excellence* settings, in which a specific type of procedure is performed by one experienced surgeon rather than multiple surgeons with limited prosthetic experience [21].

In addition to increased operative time, several studies have suggested that the increased rate of infection during revision surgery may be attributed to a bacterial colonization of the clinically uninfected prostheses [10, 22]. Some prosthetic surgeons have hypothesized that revision surgery itself may be the trigger that activates bacteria within the biofilm to become planktonic, leading to a clinically evident infection. This theory has ultimately led to the attempts at debriding the biofilm during surgical revision and serves at the foundation for the salvage protocols [23].

Beyond bacterial colonization and surgery itself, the majority of risk factors are patient-related. Treatment of preexisting urinary tract infections and documentation of sterile urine prior to the implantation is imperative [24, 25]. This principle holds true for other distant sites of active infections that can lead to hematogenous spread [9, 26].

Patients with diabetes mellitus may be more susceptible to prosthetic infections for a number of reasons. Elevated glucose levels within tissues appear to stimulate bacterial growth [27] and further promote infection by impairing chemotaxis and phagocytosis of leukocytes and adherence and oxidative burst of polymorphoneutrophils [28–31]. Additionally, diabetic men frequently suffer from compromised microvasculature, thus contributing to poor delivery of systemic antibiotic and poor or delayed wound healing [32, 33]. Reports both supporting and refuting the increased incidence of IPP infections among men with diabetes have been published. Montague and Angermeier found no difference in the infection rate for diabetic vs. nondiabetic patients [34] in a series of 491 men undergoing penile prosthesis surgery. Caire reported that diabetic men do not appear to be more likely to undergo IPP revision surgery due to infection compared to men without diabetes [5]. Bishop et al. suggested that poorly controlled diabetes with hemoglobin A1c greater than 11.5 % was predictive of the increased infection rate [35]. However, in a

series of 389 men undergoing IPP surgery, Wilson et al. failed to demonstrate that HbA1c was a statistically significant predictor of post-surgical infection [36].

Spinal cord injury may increase the risk for IPP infection. Patients with spinal cord injury have increased occurrence of urinary tract infections (or bacterial colonization), intermittent self-catheterization, and decreased penile sensation, which may increase the risk for IPP infection. In spite of theorized mechanisms of infection, spinal cord injury as an independent predictor of infection remains controversial [25, 37, 38].

Prophylaxis (Including Impregnation)

Preoperative preparation is critical in reducing the risk of infection. Given the possibility of urine spillage, sterile urine culture should be documented prior to implantation. Other skin-based sites also should be assessed for the presence of active infection. Evidence suggests that chlorhexidine skin preparation reduces bacterial colony counts on skin, and results in 40 % lower surgical-site infection rate compared with traditional providone-iodine mixture [39]. To further reduce the incidence of infection, a "no-touch" technique has been described, which minimizes the contact between the skin and surgical field [40]. Clipping or shaving hair preoperatively should be done in the operating room as opposed to earlier to reduce the risk of infection [41, 42]. An option for shaving vs. clipping genital hair should be given to the surgeon, given no increase in the infection risk and less infliction of skin trauma with the use of a safety razor [43].

Preoperative antibiotic prophylaxis is recommended by the American Urologic Association for the placement of penile implants [44]. The regimen should target the most common pathogens from the skin flora and urinary tract, which could be accomplished by administration of gentamicin with either a first-generation or second-generation cephalosporin or vancomycin. Systemic administration should be started within 1 h before the incision and continued for up to 24 h following the procedure. Many urologists will also prescribe 7–10 days of oral antibiotics following the prosthesis implantation [45].

Given the increased risk of infection following revision surgery (even for noninfectious indications) an antibiotic washout procedure should be considered. This technique is performed by forcefully irrigating the implant exposed spaces with copious solution containing antimicrobials such as bacitracin, gentamicin, rifampin, cephalosporins, hydrogen peroxide, and iodine. Reported decrease in the infection rated following revision and washout could be attributed to antibiotic solution as well as mechanical disruption and removal of the biofilm [46]. A decrease in positive implant capsule culture following a washout has been reported [47].

Penile implant manufacturers (American Medical Systems (AMS) (Minnetonka, MN, USA) and Coloplast Corporation (Minneapolis, MN, USA)) now incorporate antibiotics or the capacity to elute antibiotic into the outer coating of the implant. The AMS device is available with InhibiZone™ which is a combination of rifampin and minocycline that is annealed to the implant using a proprietary technique. In a report of 36,000 patients who received an InhibiZone-coated device, the infection rate was found to be significantly lower (1.1 %) compared with patients who received a non-coated prosthesis (2.5 %) [48]. Similar results were found in a subset of patients with diabetes, who demonstrated a lower rate of infection-related revisions in the minocycline/rifampin-impregnated group (1.62 %) compared to those who received a non-impregnated device (4.24 %) [49]. Coloplast Corporation manufactures the Titan IPP with a hydrophilic coating that can be soaked in the antibiotic solution of choice just prior to implantation. This latter option offers the theoretic advantage of choosing antiobiotics based upon specific bacterial identification. In a smaller series of patients receiving a Rifampin/Gentamicin-soaked Titan IPP, the prosthesis infection rate appears to be very low [50].

Presentation

The majority of penile prosthesis infections are subacute and are attributed to the *Staphylococcus epidermidis*, an organism of low virulence. These cases are generally not considered a urologic emergency, but may present with chronic pain associated with device or progressive fixation of the pump to the scrotal wall. Prolonged pain immediately following implant surgery may also suggest a prosthesis infection; however, in this circumstance it is difficult to differentiate between true infection and prolonged healing. When this occurs, a trial of oral antibiotics is recommended [51]. If pain improves with antibiotic therapy, infection is more likely. Mulcahy suggested using Bactrim DS for 4 weeks and to proceed to surgery if symptoms do not resolve [52].

More aggressive infections tend to occur earlier in the postoperative course, usually within 3–4 weeks and are due to more virulent organisms which cause infection in up to 20 % of the cases [34]. The grossly infected penile prosthesis is frequently accompanied by fever, pain, purulent drainage, erythema and induration over the device, and leukocytosis. Fournier's Gangrene is rare, but must be ruled out by clinical history and exam [53, 54]. If a necrotizing infection is suspected, emergent administration of broad spectrum antibiotics and surgical debridement is warranted. If there is concern related to the infection of a decommissioned prosthetic reservoir, abdominal/pelvic imaging should be considered with either ultrasound, CT scan or MRI. In this scenario, sonography may be advocated to identify fluid collections or to explore reservoir and cylinders. CT and MRI will better assess the location and condition of the components, with the latter being superior to any other method in defining soft tissue and cylinder deformities [55].

Management

The most conservative approach to management of the grossly infected penile prosthesis involves explantation of the infected device without immediate replacement with a new prosthesis. A fluid or tissue sample should be taken from the infected space and sent for immediate gram stain, culture, and antibiotic sensitivities. The implant space should be copiously irrigated, usually with antibiotic solution. If severe purulence is present, the intracorporal and intrascrotal space should be drained and the epidermis left open to heal by secondary intent. In some instances, closed suction drains may be irrigated with broad spectrum antibiotics, and after the culture results are available, culture-specific antibiotics [56, 57]. Drains should be removed when clinically indicated or after 72 h of culture-appropriate antibiotic irrigation [57, 58]. Following the initial recovery of total penile prosthesis explants, patients should be advised to consider utilizing a vacuum erection device (VED) in an effort to minimize corporal fibrosis and penile shortening [52]. Penile prosthesis replacement should be delayed for a minimum of 2 months to allow for adequate healing. Given the severity of fibrosis and anatomic distortion that can occur as a result of infection, patients should be counseled regarding the increased risk for surgical complications, including repeat infection.

In select patients with acute penile prosthesis infection, a salvage approach can be employed, whereby the infected prosthesis is immediately replaced. Severely ill patients with evidence of sepsis, necrotic tissue, rapidly developing infection, cylinder or urethral erosion should not be considered candidates for the salvage procedure. If a salvage procedure is intended, all components of the device are removed and all spaces in contact with the prosthesis are sampled for immediate gram stain and culture. All spaces should be copiously irrigated with antibiotic solution. The salvage protocol proposed by Mulcahy includes (1) irrigation with a solution of 80 mg of gentamicin and 1 g of vancomycin in 1 L of sterile saline, (2) irrigation with a solution of half strength hydrogen peroxide and half strength Betadine in 1 L of saline, and (3) pressure irrigation with up to 5 L of vancomycin/gentamicin mixture. An 18 French red rubber catheter can be used to reach the extremities of each cavity. Other variations of the antibiotic preparation have been

described including the use of kanamycin/bacitracin mixture [23]. Once the irrigation is complete, gloves, instruments, drapes, and gowns are changed, a new prosthesis is placed, and incisions are closed [59]. In Mulcahy's original report, successful reimplantation of a penile prosthesis, without clinical reinfection, was reported for 84 % of patients who underwent the salvage protocol [57]. Failures are more common if a significant cellulitis is present and more virulent organism is cultured.

Delayed salvage may also be considered. Knoll and colleagues reported successful penile prosthesis replacement in 71 % of patients who underwent IPP removal, drain placement, and antibiotic irrigation for 72 h prior to IPP replacement [60]. Although the success rate of the delayed protocol is similar to the immediate salvage procedure, it may be associated with higher cost and prolonged hospital stay, making immediate salvage a preferred method for most patients.

In a case of pump erosion, a procedure substituting penile reservoirs with malleable prosthesis has been described [61]. In this retrospective series all components of an inflatable prosthesis with infected/eroded scrotal pump are removed, followed by antibiotic washout using the Mulcahy protocol and replacement of the intracorporal cylinders with a malleable prosthesis. This approach could be considered in cases where the most severe infection appears confined to the pump (scrotum) or reservoir space and the patient does not have penile pain on palpation or evidence of systemic infection and sepsis [61]. Once the acute infection has cleared, the patient may then elect to have the semirigid device replaced by an IPP in an elective fashion. This partial salvage offers the specific advantage of removing infected components while maintaining the intracavernosal space to allow for easier revision surgery.

Summary

Penile prosthesis infections, although rare, present a highly morbid complication for the patient. Understanding the risk factors, pathogenesis and preventative measures are imperative for any provider dealing with this complication. Occasionally, penile prosthesis infection represents a true urological emergency. Recognition of a rapidly progressive infection with immediate device removal, debridement, and administration of systemic antibiotics is critical to a successful outcome. Infection with *S. epidermidis* generally presents with a more indolent clinical course and should be treated surgically with a salvage protocol and insertion of a new penile prosthesis.

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Fournier's Gangrene

11

Mathew D. Sorensen and Hunter Wessells

Introduction

Fournier's gangrene is a serious, progressive necrotizing infection of the skin, subcutaneous fat, and superficial fascia of the external genitalia and/or perineum. In 1883 Jean Alfred Fournier described the gangrene as idiopathic, of sudden presentation and rapidly developing in previously healthy young males [1]. This definition has changed substantially. Today, an underlying etiology can almost always be identified [2, 3], the disease may follow a more indolent course in certain cases, and the at-risk population is not limited to young people or to males [4–13]. Fournier's gangrene is rare, representing less than 0.02 % of hospital admissions with an overall incidence of 1.6 cases per 100,000 males [14]. Fournier's gangrene is rare in pediatric patients but the incidence increases with increasing age until it peaks and then remain steady after age 50 at 3.3 cases per 100,000 males [14]. Fournier's gangrene remains a life-threatening disease that requires early recognition with aggressive surgical debridement, resuscitation, and broad-spectrum antibiotics as the cornerstones of therapy [2–4, 15].

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Etiology and Pathogenesis

Fournier's gangrene is a synergistic infection with multiple aerobic and anaerobic bacteria [3, 4]. These include *Escherichia coli*, *Bacteroides species*, *staphylococci*, *Proteus*, *streptococci*, *Pseudomonas*, *enterococci*, and *Clostridium perfringens* [2, 3, 8, 9, 11].

Multiple comorbid conditions have been associated with Fournier's gangrene. Between 32 and 77 % of patients have diabetes mellitus [5–9, 12, 16–18]. An increase in the prevalence of diabetes has also been shown to be associated with an increase in the incidence but not mortality from Fournier's gangrene [14]. Alcoholism, immunosuppression (including acquired immunodeficiency syndrome [AIDS]) [19], malignancy, obesity, malnutrition, and intravenous drug use predispose to necrotizing genital infections [5–7, 9, 12, 16, 20]. Local trauma and surgery to the external genitalia are further risk factors [4, 12, 20].

The source of infection is identifiable in more than 75 % of cases [2, 3, 8, 9, 11]. Perirectal and perianal abscesses are both the most common and most moribund causes [4, 7–11, 18, 21]. Periurethral infection resulting from stricture disease or instrumentation with urinary extravasation

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is identified in approximately 20–30 % of cases [4, 10, 20, 21]. A scrotal abscess, epididymitis, or skin lesions, such as suprainfected sebaceous cysts, can also progress to Fournier's gangrene [4, 10].

The route of rapid spread of necrotizing infection is determined by the contiguous fascial anatomy of the external genitalia, perineum, and abdomen. Bacterial infection can spread along the dartos fascia of the scrotum and penis, Colles' fascia of the perineum, the fascia lata onto the thigh, and Scarpa's fascia of the anterior abdominal wall up as high as the axillae. Histological characterization shows dermal and subcutaneous necrosis covered by intact epidermis [22]. The primary pathophysiological mechanism of the superficial necrosis is via thrombosis of small subcutaneous arterioles in their investing fascia, which leads to ischemia, allowing polymicrobial bacterial growth and contributing to rapid extension of infection [9, 23, 24].

Presentation and Diagnosis

The findings on examination of a patient with Fournier's gangrene are characteristic; the history and secondary signs and symptoms will give clues on the source of the infection. The infection commonly starts as cellulitis adjacent to the portal of entry. Genital pain, swelling, and erythema are the most prominent symptoms [6]. Fournier's gangrene can be distinguished from acute cellulitis by the concomitant signs of systemic toxicity, including fever, mental status changes, tachypnea, and tachycardia [25–27]. On the other hand, physical findings may underrepresent the true extent of the disease. Marked progression may occur within hours, leading to crepitus and dark purple discoloration of the tissue (Fig. 11.1), followed later by sloughing, drainage, and demarcation of dead tissue.

A history of local trauma, obstructive voiding symptoms, recent instrumentation, or urethral stricture will direct further evaluation. Perirectal pain, rectal bleeding, and a history of anal fissures are suggestive of perianal or rectal sources. If the infection originates in the scrotal skin, the palpation of the scrotal contents should be normal; secondary involvement of the scrotal skin caused by an intrascrotal process should reveal abnormal intrascrotal findings on physical exam.

Laboratory analysis will often show leukocytosis and anemia as well as an elevated serum creatinine, hyponatremia, hypocalcemia, and hypoalbuminemia [24, 26, 27].

Radiographic studies can be useful when the physical exam does not allow definitive diagnosis of Fournier's gangrene, but should not delay prompt debridement in unequivocal cases. Scrotal ultrasonography is useful to delineate an intrascrotal process if physical exam is indeterminate. Scrotal and perineal ultrasound as well as plain radiographs may reveal the presence of gas in the soft tissue, a hallmark of gangrene [28–30]. Computed tomography provides a higher specificity for the diagnosis of Fournier's gangrene, as well as early and superior evaluation of disease extent by allowing assessment of the retroperitoneum for disease spread [29]. Subcutaneous or deep tissue gas is the hallmark of Fournier's gangrene and should prompt immediate surgical exploration (Fig. 11.2), though this may not be seen in all cases. Some abscesses will produce gas in the absence of necrotizing fasciitis, but these patients will still require drainage of the collection. It is likely that, left untreated, such collections could progress to Fournier's gangrene.

Retrograde urethrography is indicated when a urethral injury or urinary extravasation is suspected. This may assist in deciding whether to place a suprapubic cystostomy tube [25].

Management

Emergent Management

The treatment of Fournier's gangrene depends on rapid recognition, radical debridement of necrotic tissue, and broad-spectrum antibiotics. Intravenous hydration is initiated immediately, and a combination of intravenous antibiotics are started, including penicillin for Gram-positive organisms, a third-generation cephalosporin or aminoglycoside for Gram-negative organisms,

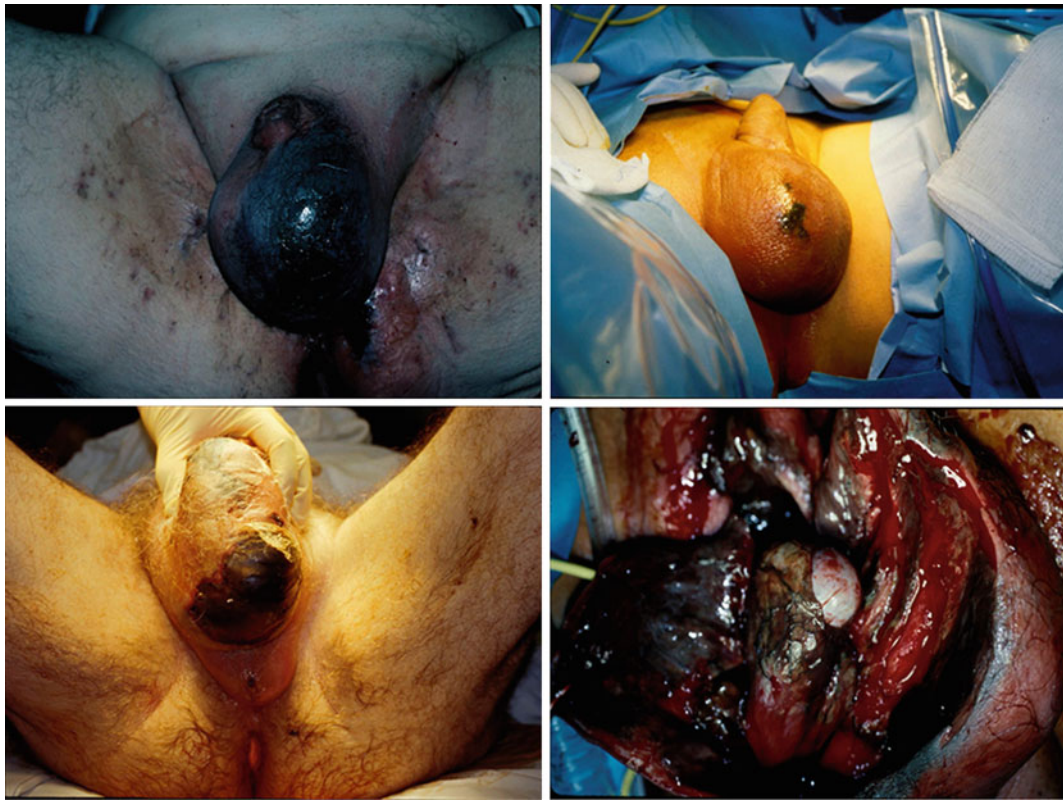

Fig. 11.1 Fournier's gangrene of the scrotum and perineum

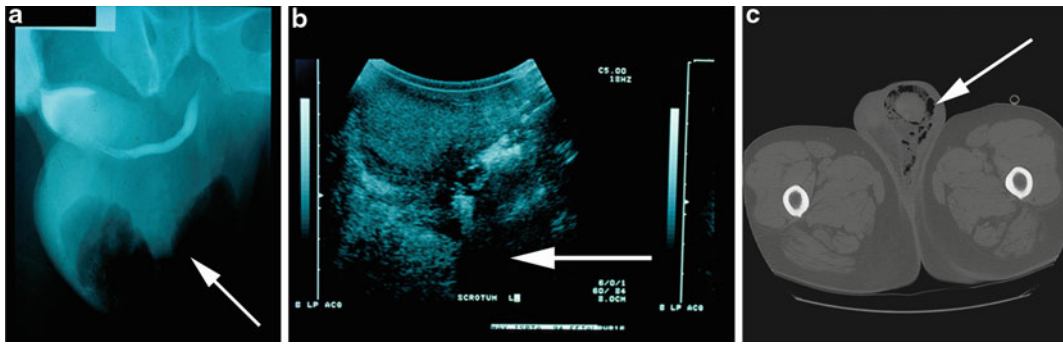

Fig. 11.2 Radiographic appearance of subcutaneous or deep gas in the soft tissues. This should prompt immediate surgical debridement. (**a**) Retrograde urethrogram plain radiograph demonstrating gas within the scrotum (*arrow*). (**b**) Subcutaneous gas on ultrasound appears as an area with high echogenicity (*arrow*). (**c**) Computed tomography demonstrating a gas-filled abscess (*arrow*)

and metronidazole or clindamycin for anaerobic organisms [3, 5]. Clindamycin may have antitoxin effects and should be used in cases where *Clostridial* infection is suspected. The critically ill patient may need correction of electrolytes, ventilatory support, and vasopressors. Purulent discharge is sent for culture from the emergency room or at the time of incision in the operating room.

Fournier's gangrene remains a surgical emergency. Aggressive, sharp excision of all devitalized skin, subcutaneous tissue, and fascia

is performed expeditiously. Debridement is extended into vital tissue at all margins. The glans penis, corpus spongiosum, corpora cavernosa, and testes are almost always preserved because of their deep blood supply, which is independent of the compromised fascial and subcutaneous circulation. The perineal artery, a branch of the internal pudendal artery, supplies the skin and superficial fascial planes of the perineum and posterior scrotum. The blood supply to the skin and dartos fascia of the anterior scrotum and penis is derived from the external pudendal branches of the femoral artery.

Buck's fascia on the penile shaft and the corpora are uninvolved by the necrotizing process because they receive blood from the dorsal, cavernosal, and bulbar arteries, which are further branches of the internal pudendal artery. The spermatic fascia, tunica vaginalis, and testes are supplied by the cremasteric, vasal, and testicular arteries, respectively, and are generally spared from necrotizing gangrene. These structures rarely require debridement and should be preserved. Once the tunica vaginalis has been violated, suprainfection of the testis is more likely and may necessitate secondary orchiectomy. Primary orchiectomy should be performed at the time of debridement if the etiology of the necrotizing infection is epididymo-orchitis or scrotal abscess [20].

We perform debridement with scalpel, scissors, and 0 chromic suture ligatures rather than electrocautery, which is more time consuming. Significant hemorrhage may occur and necessitates careful hemostasis. Intraoperative proctoscopy and cystoscopy are performed when indicated for suspected rectal or urethral sources of infection [25].

Large complex wounds with massive contamination and simultaneous colorectal or urinary tract disease may necessitate fecal or urinary diversion. Fecal diversion is achieved with end colostomy, and suprapubic cystostomy is preferred for urinary diversion [10, 12, 18, 31]. Our experience has been that few patients require colostomy, and Foley catheter drainage is sufficient in the absence of urethral stricture of fistula.

Repeat inspection and debridement should be scheduled within 24 h; two to four surgeries are commonly required for each patient [5, 7, 10, 12, 17, 20, 32, 33]. It remains controversial whether the denuded testes should be placed in thigh pouches (Fig. 11.3) or kept free and wrapped in moist gauze dressings. Until the wound bed is free of gross contamination, the testes should be kept in standard dressings. Once the wound becomes clean, the thigh pouch offers the advantage of easier dressing changes and less patient discomfort. In cases of isolated scrotal gangrene, placement of the testes in thigh pouches may allow primary closure of the perineum and more rapid discharge of the patient. Scrotal reconstruction can then be planned electively. It is important to place the testes anteriorly to avoid compression and pain with adduction. The rare patient may prefer to leave the testes in thigh pouches.

The majority of patients will have additional areas of skin loss of the penis, perineum, thighs, or lower abdominal wall. In such cases, we leave the testes exposed: Delayed scrotal reconstruction with skin grafts at the time of coverage of other reconstruction makes sense (*see* "Coverage" section).

Postoperative Management

Debrided wounds are left open, and aggressive wound care is initiated postoperatively with saline gauze dressings, whirlpool or waterpick therapy, and repeat debridement. This prepares the wounds for secondary coverage. Intravenous antibiotics are stopped when the wound is clean. Quantitative cultures may be used to estimate suitability of the wound for reconstruction. Important postoperative concerns include the careful control of diabetes and sufficient caloric and protein intake to allow adequate wound healing. Attention to supportive care is also important as up to 10 % of cases may require mechanical ventilation, and almost 2 % may require dialysis [14].

Hyperbaric oxygen therapy may be used as an adjunct after rapid debridement [4, 16, 20, 25]. High oxygen tension is thought to improve wound healing and mitigate ongoing necrosis in the hypoxic tissues at the margins of the debrided field. Mechanisms may include stimulation of leukocyte function, enhanced neovascularization,

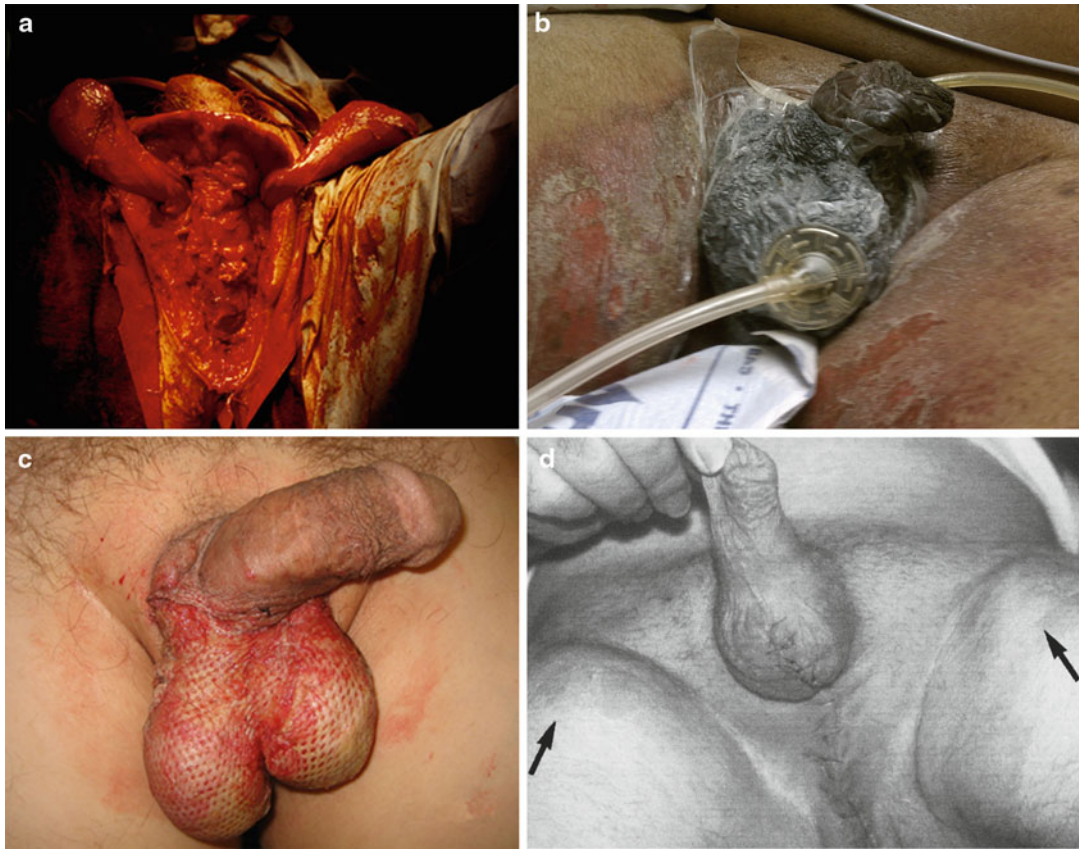

Fig. 11.3 Scrotal defect and options for closure. (**a**) Primary defect. (**b**) Vacuum-assisted closure (VAC) device applied to the scrotum. (courtesy of Thomas G. Smith, MD, Baylor College of Medicine). (**c**) Scrotal wound coverage with cadaveric allograft. (**d**) Testicles placed into thigh pouches (*arrows*) and primary closure of the wound

and inhibited toxin formation by anaerobic bacteria [14, 20, 34]. Therapy is typically initiated as soon as possible after debridement with as many as three dives within the first 24 h, with decreasing dive frequency until 5 days after surgical wound closure [20]. Patients must be medically stable and able to tolerate relative isolation from medical care for 1–2 h. Hyperbaric oxygen appears to work best if initiated early in the treatment of a necrotizing soft tissue infection, and this is the time when patients are the least stable. If infection is controlled rapidly and completely with conventional treatment, hyperbaric oxygen may be unnecessary [34, 35]. Hyperbaric oxygen treatment may decrease mortality, but the current evidence consists primarily from case-series and thus there is divergence in the literature as to its benefits [20, 36].

The topical application of honey is an adjunctive treatment that has been advocated when hyperbaric oxygen is not accessible [12, 37, 38]. Unprocessed honey has a pH of 3.6 and is thought to contain enzymes that promote digestion of necrotic tissue. It also has topical antibacterial activity and increases local oxygenation [12].

Coverage

Once the wound bed is clean and clear of infection, reconstruction is based on the size of the defect, the presence or absence of the testes, sexual function, remaining transferable genital skin, and overall patient status [39]. Reconstruction is typically planned once wounds are clean and granulating,

usually 7–21 days after initial debridement. Patients may be able to perform dressing changes at home or in a skilled facility while waiting elective reconstruction, especially if their wounds are small.

Recently, vacuum-assisted closure (VAC) devices have been used once the wounds are stable and no longer require daily evaluation (Fig. 11.3). These negative pressure devices are believed to improve wound healing by encouraging perfusion, fibroblast migration, and cell proliferation. They also remove excess exudates, reduce edema, and draw the wound edges together. Prospective randomized control trials have demonstrated improved wound healing and decrease in wound surface area in patients treated with VAC devices compared to conventional gauze therapy alone [40]. These devices also decrease patient discomfort with dressing changes, improve patient mobility, and decrease hospital length of stay by speeding wound closure [40–43]. It may decrease the need or extent of wound coverage and allow earlier reconstruction, though they can sometimes be challenging to place [44].

We have used human cadaveric skin allografts as temporary biological dressings to reduce the frequency of dressing changes and to prepare the wound for skin autografting. The allograft is typically placed for 5–7 days to promote neovascularization and re-epithelialization of the wound, and is then removed at the time of skin grafting (Fig. 11.3).

Split-thickness skin grafting (STSG) remains the preferred method of penile skin replacement due to its versatility, relative ease of use, and consistent take [45, 46]. Meshing of the STSG allows the wound to drain and may have better take in debilitated patients or those with contaminated wounds. Meshed STSG has been used in impotent men where wound contraction is not a concern [46]. Unmeshed STSG is typically used in potent men, although we have used unexpanded (e.g., 1:1) meshed STSG in men with various etiologies of penile skin loss, and have demonstrated excellent graft take with no function impairment regardless of sexual function (Figs. 11.4 and 11.5) [47]. Others have reported wound coverage with remnant foreskin [48] and scrotal skin [49], but full-thickness skin grafting is typically avoided in Fournier's gangrene [50].

Scrotal reconstruction is more challenging. When defects are large and primary wound coverage is impossible, flaps or meshed STSG

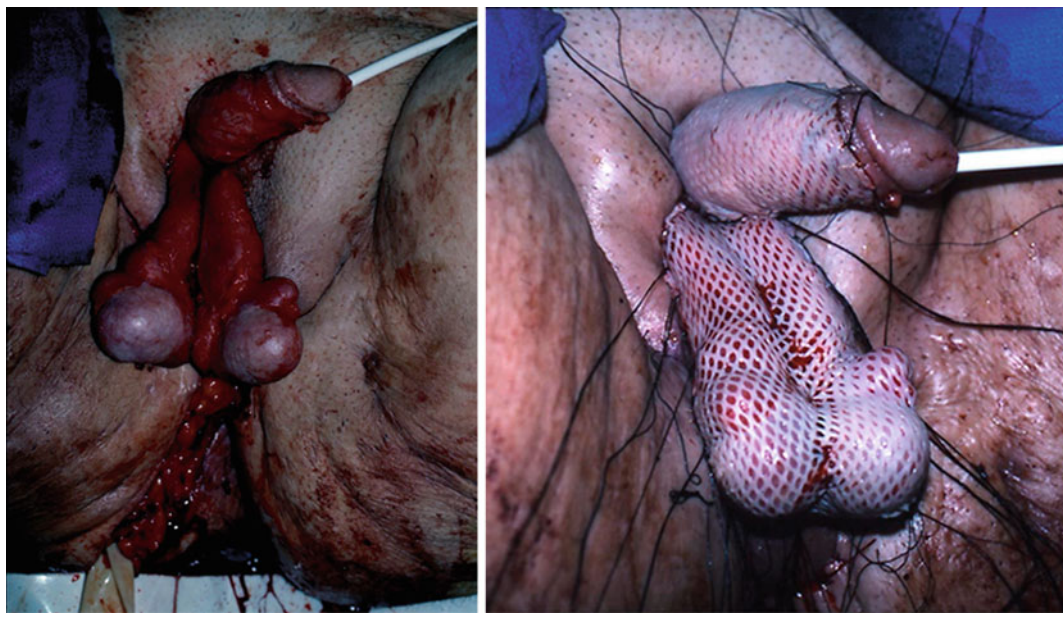

Fig. 11.4 Split-thickness skin graft to the penis and scrotum with primary closure of the perineum

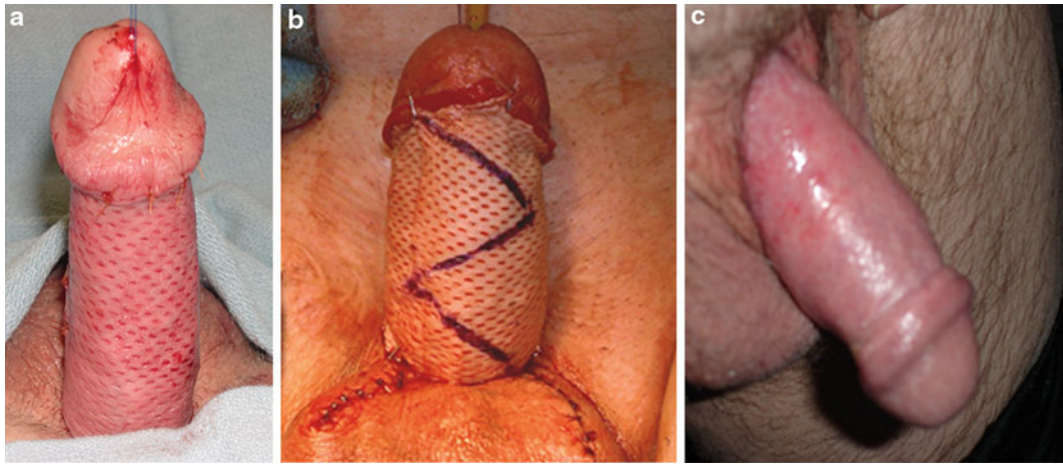

Fig. 11.5 Details of unexpanded 1:1 meshed split-thickness skin graft to the penis. (**a**) Dorsal view. (**b**) Ventral view demonstrating z-plasty of the graft to allow for slight contraction. (**c**) Follow-up picture after recovery with near 100 % graft take

may be used though this may require a staged closure with rotational or advancement flaps [51–53]. Flaps are preferred by some for purported improvement in functional outcome, with a resultant sensate and hair-bearing scrotum [54]. Tissue expanders have been used to reconstruct a two-compartment scrotum when there is at least a small remnant of scrotal skin [55]. If a STSG is already planned to cover a penile or abdominal wound, a meshed STSG should be used for scrotal reconstruction. We prefer meshed STSG due to its availability and excellent take. Perineal defects provide a suboptimal graft bed, and residual defects in adjacent areas typically heal well by secondary intention. When possible, remnant scrotal or medial thigh skin can be reapproximated to reduce the size of the perineal defect.

Prognosis

Despite maximal medical and surgical treatment, Fournier's gangrene remains a potentially lethal disease. Most studies report mortality rates of 20–40 % with some studies reporting fatality rates as high as 88 % [56]. These data tend to come from small series at tertiary referral centers. With each passing decade, the mortality rate has decreased but morbidity remains high [14].

Several factors appear to be associated with mortality. Advanced age may be the most important independent predictor of mortality, increasing the risk of death 4–15-fold [9, 11, 24, 32, 57]. More extensive disease may predict a poor outcome [11, 16, 57] and a colorectal or perianal source also appears to confer a worse prognosis [4], which may be related to delay in diagnosis and more extensive disease. Deaths tend to occur late during hospitalization. Although Fournier's gangrene is less common in women, they may have a higher mortality rate [7, 58].

Hospital experience with Fournier's gangrene also appears to be related to mortality. Most hospitals (up to 66 %) care for no patients with Fournier's gangrene, and less than 1 % of hospitals care for five or more cases in a given year [14]. Hospitals that treat more Fournier's gangrene patients have lower mortality rates; [32] they likely care for the most severely ill patients but are more likely to offer the substantial resources required for the treatment of these patients. Further regionalization of care for patients with Fournier's gangrene may help to improve access to an experienced multidisciplinary team, including urologic surgeons, general surgeons, intensivists, and plastic surgeons, which is important for these severely ill patients.

There have been previous attempts to predict mortality in patients with Fournier's gangrene with the Fournier's Gangrene Severity Index using patient vital signs and laboratory tests to calculate a score that may potentially be used to monitor therapy and predict patient mortality [57]. This index is based on the Acute Physiology and Chronic Health Evaluation II classification system and consists of admission vital signs (temperature, heart rate, respiratory rate) and laboratory values (hematocrit, white blood count, serum sodium, potassium, creatinine, and bicarbonate). However, the Fournier's Gangrene Severity Index was developed using retrospective data gathered from 30 patients over a 15-year period and thus has had variable accuracy in predicting mortality [59–67]. Others have tried to improve the prediction of the index by including the extent of skin involvement [68]. Furthermore, Fournier's gangrene may take a fulminant course in the immunocompromised patient [16], although some reports indicated no worse prognosis in human immunodeficiency virus (HIV)/AIDS [2, 9, 11]. Diabetes has not been predictive of a poor outcome because of its high prevalence in this patient population.

Morbidity from Fournier's gangrene remains high. Cases often require multiple operations, orchiectomy, cystostomy, and/or colostomy [7, 12, 20, 33]. In patients that do not undergo surgical wound closure, the burden of wound care after discharge from the acute hospitalization can be tremendous. As many as 30 % of survivors may require ongoing care after discharge in the form of home health care or a skilled nursing facility stay [32].

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Part III

Vascular and Hemorrhagic Emergencies

Renal Artery Embolism and Renal Vein Thrombosis

12

Jason R. Woo, Edward J. Yun,
and Christopher J. Kane

Renal Artery Embolism and Infarction

Renal artery thrombosis was first described by Von Recklinghausen in 1861 [1]. The first successful revascularization was performed by Rohl in 1971 [2]. With the advent of diagnostic modalities such as spiral computed tomography (CT) and magnetic resonance imaging, as well as the development of thrombolytics and percutaneous methods of embolectomy, the clinical approach to this condition has changed significantly over the past 30 years. Although prospective studies are lacking because of the relative rarity of this condition, an accumulation of retrospective data on treatment and outcomes exists and can provide some guidance toward optimal therapy.

Renal artery occlusion has many etiologies, some of which are listed in Table 12.1. In general, these can be divided into spontaneous, traumatic, and iatrogenic causes, which present differently and have varying approaches to management. We therefore discuss each of these categories of renal infarction separately.

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Spontaneous Renal Infarction

Cardiovascular disease is the most common predisposing condition leading to spontaneous renal infarction. Reviews have shown that 65 % of affected patients had a history of atrial fibrillation, 53 % had hypertension, and 41 % had evidence of ischemic heart disease [3]. Other medical conditions that increase the risk of spontaneous renal artery embolism and infarction include hypercoagulable states, renal artery aneurysm, and inflammatory disorders such as polyarteritis and fibromuscular dysplasia.

Incidence and Presentation

The true incidence of spontaneous renal infarction is unknown. Autopsy studies have found an incidence of 1.4 % [4], although clinically significant events are uncommon, occurring in an estimated 6.1 per million hospitalized patients [5]. Common presenting symptoms in patients with renal artery thrombosis include abdominal or back pain, nausea/vomiting, costovertebral angle tenderness, and hypertension. The most common symptom is flank pain, found in 65–77 % of cases [3, 6]. These symptoms may masquerade as renal colic, pyelonephritis, cholelithiasis, lower back disease, and myocardial infarction; often an embolic event to the kidney is not suspected. Acute hypertension at presentation is thought to be renin-mediated [7].

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Table 12.1 Etiologies of renal infarction

Spontaneous renal infarction
Cardiovascular
Atrial fibrillation
Ischemic heart disease
Mitral stenosis
Endocarditis
Atherosclerosis
Hypertension
Autoimmune
Polyarteritis nodosa
Systemic lupus erythematosis
Fibromuscular dysplasia
Behcet's disease
Henoch–Schonlein purpura
Other
Drug abuse
Hypercoagulable states
Malignancy (e.g., bronchial cancer)
Chagas disease
Polycythemia vera
Acquired renal infarction
Trauma
Blunt injury
Penetrating injury
Surgical procedures (Iatrogenic)
Renal transplantation
Cardiac valve repair
Endovascular stenting
Angiography
Interventional polymers

Diagnosis

Laboratory investigation plays a limited role in the diagnosis of renal infarction. Microscopic hematuria has been reported in 60–80 % of cases, and pyuria less frequently. Leukocytosis has been reported in 71 % of identifiable cases [6]. Most patients at presentation have or will develop an elevated serum lactate dehydrogenase (LDH) as renal tissue becomes nonviable. While highly sensitive, LDH has poor specificity in this context. Serum creatinine may be elevated, but existing data are unclear given the high rate of nephrotoxic contrast exposure in these patients, who are often imaged at presentation [7]. Although inconsistently elevated, other laboratory tests that may be found to be abnormal in renal infarction include aspartase aminotransferase, alkaline phosphatase, C-reactive protein, and fibrinogen [3].

Renal artery occlusion should be suspected when a patient at an increased risk for thromboembolism presents with the aforementioned signs and symptoms. Diagnostic confirmation can be achieved using arteriography, intravenous urography (IVU), radionuclide scintigraphy, magnetic resonance imaging, or ultrasound, but the most commonly utilized mode of reliable, rapid identification of arterial occlusion has been CT [6]. Although all highly sensitive, radionuclide scintigraphy and IVU are rarely used in this context today, and the invasiveness of renal arteriography prevents its use as a first-line study. A more current diagnostic strategy for suspected renal infarction is CT with and without IV contrast and consideration of MR angiography in those for whom IV contrast cannot be administered.

Radiological findings of an embolus include a filling defect in the renal artery and lack of enhancement of the affected kidney. In some cases, an abrupt cutoff of an enhancing renal artery may be seen in the presence of normal renal contour and a central renal hematoma [8]. Spontaneous renal emboli appear to involve the left kidney more frequently, which is attributed to the more acute angle of the left renal artery off the aorta.

Treatment

Standard treatment strategy includes anticoagulation with or without thrombolytic therapy. Percutaneous or surgical interventions are more often considered in cases of solitary kidney, bilateral involvement, complete artery occlusion, or failure of medical management. Outcome literature has been limited to case reports and retrospective reviews, and controversy still exists regarding the optimal choice and timing of treatment.

Nonoperative management for spontaneous renal infarction includes anticoagulation and fibrinolytics. Patients are typically anticoagulated with IV heparin and oral warfarin to prevent further embolic events. Thrombolytic therapy can be given systemically or locally, although local infusion with selective catheterization is the preferred approach. Typical local thrombolytic therapy involves continuous infusion of an agent such as streptokinase, urokinase, or

tissue plasminogen activator to the affected artery. There are data to suggest that thrombolytic therapy does not improve outcomes once the ischemic tolerance of the kidney has been exceeded. This is thought to occur after roughly 180 min of ischemia, although the length of time to irreversible ischemic injury is debated [9]. It is generally accepted that, under physiological temperatures, a kidney becomes nonviable following 60–90 min of total circulatory arrest [10]. Both animal studies and human retrospective reviews, however, have shown persistent renal function in longer intervals of occlusion. This variability is thought to be due to the frequent presence of collateral circulation.

Surgical repair in cases of renal infarction with a normal contralateral kidney remains controversial given the higher morbidity of open revascularization and lack of evidence supporting benefits in terms of renal function. It is, however, preferred for patients with traumatic renal artery thrombosis when surgery is done within the first few hours after injury. Those supporting immediate surgical correction via open thromboembolectomy or bypass grafting argue that renal salvageability cannot accurately be assessed, and thus all efforts should be made for immediate restoration of blood supply [11]. Surgical techniques that have been described include thrombectomy with end-to-end reanastamosis, autotransplantation, or aortorenal saphenous vein bypass graft, among others. Some investigators have suggested that attempt at surgical revascularization should be made if the presumed warm ischemia time is less than 5 h.

In cases of bilateral renal artery occlusion or renal infarction in a solitary kidney, attempt at surgical or thrombolytic revascularization is indicated regardless of ischemia time. With success defined as renal function able to sustain life without dialysis, Lohse et al. reported that successful surgical revascularizations were performed in 4 of 10 patients with bilateral renal artery thromboses [12]. Similarly, there have been reports of restoration of renal function in bilateral renal artery thrombosis using thrombolytic therapy [13, 14].

Percutaneous thromboembolectomy has been shown to be a viable option for renal artery thrombosis. Successful rheolytic aspiration via hydrodynamic catheterization has been described for renal artery and other visceral emboli [15, 16]. This and other minimally invasive, mechanical techniques hold promise and may replace surgical embolectomy in select patients.

Prognosis

In the most recent outcome review of renal artery embolism, Kansal et al. showed that renal function outcomes are favorable in the majority, with 57 % of patients regaining normal renal function and 16.7 % having mild renal impairment with creatinine less than 2 after treatment. Mortality was typically a result of recurrent embolic disease or heart disease and not due to renal complications [7].

Acquired Renal Artery Infarction

Renal Infarction Caused by Surgical Procedures

Renal transplantation and other procedures involving vascular anastomoses predispose patients to the risk of renal artery occlusion. In a review of complications of more than 1,200 renal transplants, Osman et al. found that 0.4 % of transplants are complicated by arterial thrombosis, and that ischemia and complications of treatment can lead to transplant loss [17].

The diagnosis of vascular occlusion can be challenging. Late renal artery stenosis presents with worsening hypertension and decreased renal function. Early arterial occlusion typically presents with acute oliguria, with Doppler ultrasound images suggestive of poor perfusion. In this setting, the differential diagnosis includes acute rejection, acute tubular necrosis, cyclosporine toxicity, and renal vein thrombosis (RVT) [18]. Diagnosis is confirmed with arteriography, and interventional techniques can be employed acutely.

Renal artery complications after transplant can also be managed with open revision. Takahashi et al. recently reviewed the diagnosis and management of renal allograft perfusion failure caused by dissection [19]. The authors believe interventional techniques such as stenting are

superior to open revision because of decreased treatment-related complications and less chance for graft loss.

Percutaneous endovascular procedures, such as endovascular stenting, have also led to renal embolic events. In a review of complications related to renal artery stenting for renal artery stenosis, Ivanovic et al. found that 2.6 % of patients undergoing these procedures suffered from renal artery thrombosis in the postoperative period [20].

Renal Infarction in the Setting of Trauma

Renal infarction secondary to trauma can result from either penetrating or blunt injury. Although the mechanism of injury is clear for penetrating wounds, the etiology of renal occlusion in blunt trauma is not completely understood. Most investigators believe that rapid deceleration leads to stretching and subsequent disruption of the intimal layer of the renal artery, with resultant thrombosis. This thought is supported by findings that the left kidney, which is less supported by surrounding organs and thus more susceptible to stretch injury and intimal tearing, is more frequently involved than the right [21]. Others suggest that direct trauma to the artery accounts for the thrombotic event. Renal artery thrombosis resulting from trauma is infrequent, with an incidence of 0.1 % in all blunt abdominal trauma admissions [22] and only about 400 cases reported in the literature [23].

There are several considerations to be made specific to cases of renal infarction caused by trauma. First, there is the emergent need to exclude a main renal artery laceration and other intra-abdominal injuries that may indicate immediate exploratory laparotomy. Thus, in a patient stable enough to undergo imaging, spiral CT is preferred over possibly more time-consuming studies such as arteriography. If an occlusion is discovered, the decision for immediate vs. delayed operative intervention may be obviated by a concomitant intra-abdominal injury for which the general surgeons will explore the patient.

When exploring trauma patients with suspected renal vascular injuries, early vascular control is imperative. McAninch and Carroll found that early vascular control during explorations for renal trauma reduced nephrectomy rates from 56 to 18 % [24]. Specific techniques that may be required for renal arterial injuries include direct repair or resection with end-to-end anastomosis or bypass grafting using vein or synthetic material [25].

Renal Vein Thrombosis

RVT predominantly affects two subpopulations: neonates with risk factors for clotting abnormalities and adults with nephrotic syndrome. We consider the diagnosis and treatment options of these two populations separately, discussing the disease process in adults first.

Etiology

The most common medical cause of RVT in adults is nephrotic syndrome. This association was identified as early as 1840, when Rayer described thrombosis of the renal veins and inferior vena cava in a patient with proteinuria [26]. In nephrotic patients, the combination of low serum albumin, high fibrinogen levels, low antithrombin III levels, and hypovolemia predisposes to the development of thrombotic disease [27]. Membranous glomerulonephritis has been identified as the most common nephrotic state resulting in RVT, accounting for up to 62 % of cases [28]. Other hematological abnormalities that have been inconsistently described include platelet hyperaggregability, thrombocytosis, and elevations of proteins C and S.

Presentation

Like renal artery occlusion, the diagnosis of RVT is commonly missed, especially in the presence of a normally functioning contralateral kidney. The finding is usually made when a patient with clotting abnormalities presents with worsening renal function, flank pain, or peripheral edema. In some instances, patients are not identified until they present with complications of the renal thrombus and hypercoagulable state, such as pulmonary embolism.

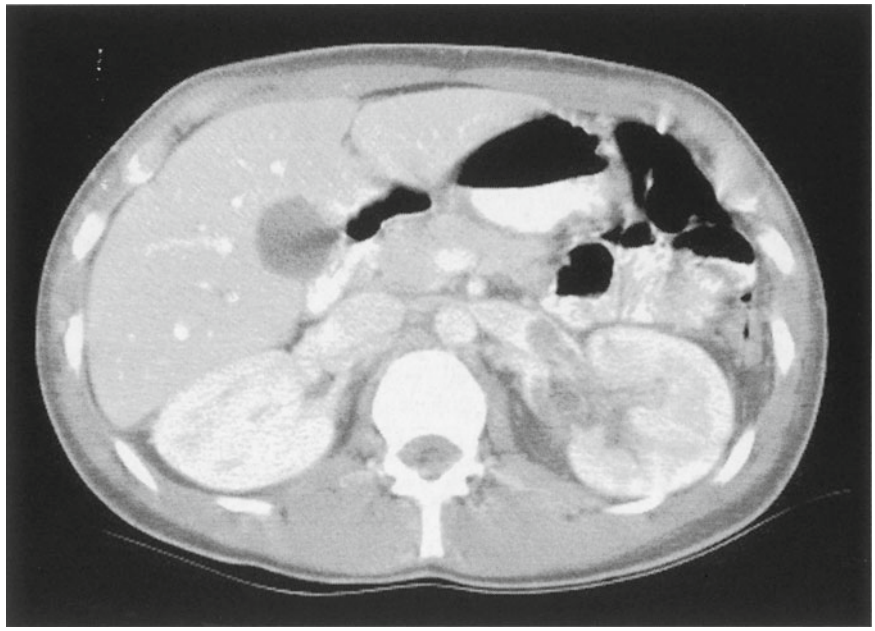

Fig. 12.1 Left main renal vein thrombus in a 27-year-old woman with the nephrotic syndrome

It should be noted that symptoms of flank pain, costovertebral angle tenderness, worsening proteinuria, and hematuria may be absent in the majority of cases. McCarthy et al. found that local symptoms were present in only 34 % of patients with RVT [29]. More commonly, the presentation is related to the nephrotic syndrome, with progressive ankle swelling and mild-to-moderate deterioration in renal function. In a prospective screening evaluation of 151 nephrotic patients, 33 had RVTs and 29 of these patients had peripheral edema only, suggesting that the majority of cases go undiagnosed or are diagnosed at a later time [30].

Diagnosis

Given the lack of specific clinical manifestations and diagnostic laboratory tests, imaging is the cornerstone of diagnosis of RVT. CT with intravenous contrast is the current imaging of choice, with sensitivity and specificity nearing 100 % (Fig. 12.1) [31]. It also allows for identification of other renal pathology. Magnetic resonance angiography (MRA) is an alternative modality that avoids radiation exposure and nephrotoxic contrast, but is costlier, more time-consuming, requires anesthesia in certain populations, and has marginally inferior sensitivity and specificity compared to CT [32]. Renal ultrasound lacks sensitivity for segmental thromboses, but has been used extensively in renal transplant recipients to detect RVTs and flow in the renal vein and artery. IVU may show swelling of the kidney from venous congestion, as well as a notching of the ureters or renal pelvis from impingement of dilated, tortuous collaterals vessels [33]. However, these findings are neither specific nor sensitive for RVT, thus IVU is rarely used in settings where more advanced imaging is available. If an interventional radiological procedure is elected, inferior venacavography and selective renal venography remain the gold standard.

Therapy

The rationale for immediate intervention in RVT in adults is to prevent further thromboembolic events and to maintain renal function. In the past, the treatment of RVT was primarily surgical, involving thrombectomy or nephrectomy. Surgical management is now rare, and anticoagulation with systemic unfractionated heparin followed by outpatient management with warfarin has

Table 12.2 Indications for thrombectomy/thrombolysis in RVT[a]

Refractory to medical intervention
Bilateral RVT
Solitary kidney
Contraindication to systemic anticoagulation
Renal transplantation
Intractable pain
Onset of complications (e.g., pulmonary embolus)

[a]Adapted from Ashgar et al. [31], with permission

been the standard treatment to prevent propagation of the thrombus [34]. The use of low-molecular-weight heparins also has been described, with the advantage of increased bioavailability, longer half-life, and potentially fewer drug interactions compared to warfarin [35]. A disadvantage of low-molecular-weight heparin is the difficulty in reversing anticoagulation should complications caused by therapy arise. Duration of anticoagulation varies from a minimum of a year to lifelong, depending upon recurrence of RVT or continued presence of risk factors [31].

Mechanical thrombectomy and/or thrombolysis via percutaneous intervention are suitable in select cases (Table 12.2). Chemical thrombolysis with agents such as streptokinase, urokinase, and recombinant tissue plasminogen activators [36] can be administered systemically or locally, although administration via catheter is associated with fewer systemic side effects. More recent advances have been made with mechanical thrombectomy via sheath access of the femoral vein under fluoroscopic guidance. In select populations, percutaneous catheter-directed thrombectomy with or without thrombolysis for acute RVT is associated with a rapid improvement in renal function and low incidence of morbidity [37].

Prognosis

The prognosis of RVT in adults has been dependent on several factors, including the presence of preexisting renal insufficiency and type of nephropathy. In a review of 27 nephrotic patients with RVT, Laville et al. reported 40 % mortality within 6 months of diagnosis with RVT, primarily due to pulmonary embolism, hemorrhagic complications, or the patient's underlying disease process. In those who survived, 12 of 16 (75 %) had stable renal function at follow-up [38]. The most important prognostic factor associated with favorable outcome was normal baseline renal function. This study also confirmed increased survival in patients with membranous glomerulonephritis compared to those with other forms of the nephrotic syndrome, such as minimal change disease and focal segmental glomerulosclerosis.

Renal Vein Thrombosis in Children

Etiology

In the pediatric population, RVT is primarily a neonatal disease, with 83 % of cases in children occurring within the first month of life [39]. It is the most prevalent non-catheter-related thromboembolism during the neonatal period [40]. The pathophysiology is assumed to be decreased renal blood flow in a child with preexisting risk factors for thrombus formation. These include severe dehydration, hypotension, cardiac disease, polycythemia, protein C deficiency, and factor V Leiden heterozygosity. Additional prenatal and perinatal risk factors include preeclampsia, maternal diabetes, traumatic birth, and fetal distress.

Presentation

Presentation of infant RVT has been classically described as the "diagnostic triad" of palpable abdominal mass, gross hematuria, and thrombocytopenia. While uncommon for all three signs to be present, a recent review showed the majority had at least one of the cardinal signs present: 56 % with gross hematuria, 45 % with palpable abdominal mass, and 47 % with thrombocytopenia [41]. Male children are affected twice as often as females and the left renal vein is affected twice as often as the right [42]. Clinical suspicion should thus also include maternal and infant risk factors, and the presence of a combination of these should warrant an investigation for RVT.

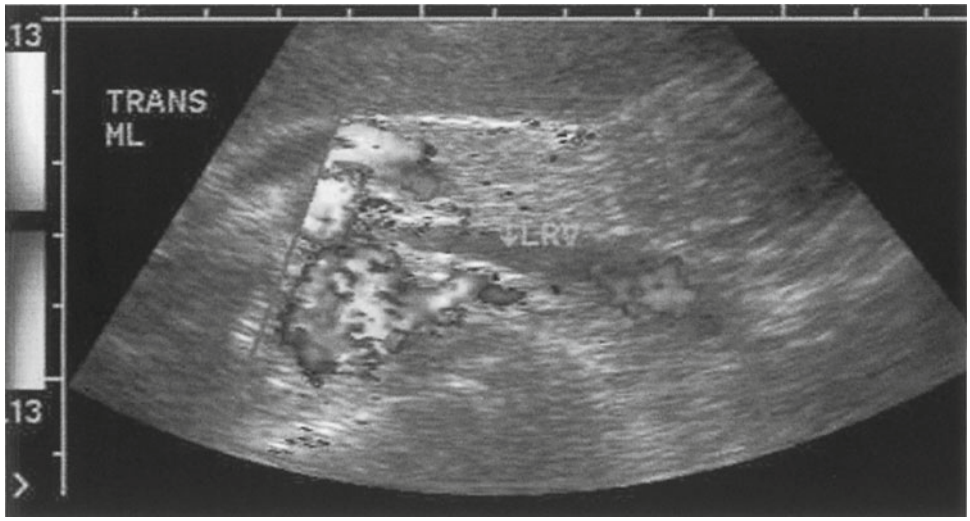

Fig. 12.2 Doppler ultrasound image of an infant with left renal vein thrombosis

Diagnosis

Once clinical suspicion is established, the best diagnostic test of RVT in children is Doppler ultrasound (Fig. 12.2). This modality is highly sensitive in infants, detecting 22 out of 23 cases in a modern study [39]. If non-diagnostic, a CT scan may be utilized. The radiological appearance of neonatal RVT includes renal enlargement and ischemia and can be confused with other causes of renal enlargement such as Wilms' tumor, pyelonephritis, and renal abscess. The radiological appearance depends on the acuity of the radiological study, because neonatal RVT evolves in appearance. Early, the kidney swells and appears echogenic on ultrasound; later, the appearance becomes more heterogeneous, with a loss of corticomedullary differentiation [43].

Treatment

Children with RVT have also been treated successfully with anticoagulation. The use of a thrombolytic agent such as recombinant tissue-type plasminogen activator has been reported in the literature [44], although intraventricular hemorrhage is a significant risk in this population, especially in the case of premature infants where deaths have been reported [45].

There are no evidence-based guidelines nor consensus for the management of neonatal RVT, although the most recent review of practice patterns shows that 40 % of patients received supportive care, 41 % received heparin or low-molecular-weight heparin, 11 % received thrombolytic therapy, and the rest some combination thereof [37]. A review of 23 children with a mean follow-up of 42 months showed that patients who did not receive anticoagulation all developed renal function impairment, while reduced renal function was seen in only 33 % of those who had received heparin [39]. However, more recent reviews demonstrate irreversible renal damage of upwards of 70 % at follow-up, regardless of anticoagulation having been administered. Long-term hypertension is found in 19 % of patients, affirming the need for close surveillance of children with RVT [40].

In summary, RVT should be suspected in neonates who have maternal or fetal risk factors with associated abdominal mass, hematuria, or thrombocytopenia. It should also be considered in adults with nephrotic syndrome who present with symptoms of colic, especially in those with membranous nephropathy. Treatment consists of supportive care and anticoagulation, with consideration of thrombolytic therapy or percutaneous interventions in select cases. With this regimen, mortality and morbidity of this condition can be minimized.

Summary

Renal artery embolism or thrombosis should be considered in the differential diagnosis of a patient with acute flank pain, particularly patients with risk factors such as atrial fibrillation, hypercoagulable disorders, or autoimmune disorders. Clinical suspicion is the key to prompt diagnosis and appropriate therapy, usually with anticoagulation or directed thrombolytic therapy.

Acquired renal artery infarction can occur from trauma or from surgical procedures such as renal transplant or vascular procedures. The specific treatment depends on the clinical situation and may be anticoagulation, endovascular procedures, or open thrombectomy or revision.

RVT occurs primarily in two populations: adults with nephrotic syndrome and infants with hypercoagulable conditions. Adults with nephrotic syndrome may present with flank pain or worsening renal function and edema. Diagnosis is usually by CT. Therapy is usually with systemic anticoagulation. The prognosis depends on a patient's renal function and whether other thrombotic complications can be avoided.

Pediatric RVT occurs most commonly in newborns of diabetic mothers or with risk factors for thrombosis such as dehydration, polycythemia, or protein C deficiency. The presentation is classically hematuria, palpable abdominal mass, and thrombocytopenia. The diagnosis is usually established with renal Doppler ultrasound. Treatment is anticoagulation or directed thrombolytic therapy, although the risk of cerebral hemorrhage is present, particularly in premature infants.

Through clinical suspicion, appropriate diagnostic testing, and prompt therapy, the late sequelae of renal vascular emergencies can be minimized.

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Retroperitoneal and Upper Tract Hemorrhage

13

Frank N. Burks and Richard A. Santucci

Introduction

Massive bleeding from the upper urinary tract (kidney and ureter) can present as either retroperitoneal hematoma or brisk hematuria. Retroperitoneal hemorrhage (RPH) secondary to a urological condition is an uncommon entity that can result from a variety of causes. It may result from local pathology involving either the kidney or adrenal or may be secondary to a bleeding disorder or systemic illness. RPH can present acutely or may have an insidious course. Due to its varying presentation and etiology, it represents a diagnostic challenge and may be associated with significant morbidity and mortality. It is essential for the urologist to be aware of the common etiologies and diagnoses and treat them promptly to ensure a successful outcome.

Brisk hematuria from an upper tract source can also be diagnostically challenging, as successful treatment will rely on accurate determination of the cause of bleeding. Most of the renal lesions that present with RPH can also present with hematuria if the lesion ruptures into the renal calyces. The resulting hematuria is rarely life threatening in the acute situation. Brisk hematuria can also result from a fistulous connection between the ureter and iliac artery, which is uncommon, but potentially fatal.

Etiology

Retroperitoneal Hemorrhage

RPH can arise from either the kidney or the adrenal gland, although rupture of an abdominal aortic aneurysm is the most common cause of retroperitoneal hematoma and should be excluded (Fig. 13.1). RPH may occur because of specific renal disorders such as tumors and cysts, or systemic causes such as bleeding disorders, anticoagulant therapy, and polyarteritis nodosa.

Renal Causes of RPH

Neoplastic

Malignant

Tumors of the kidney are the most common renal source for spontaneous retroperitoneal bleeding accounting for 57–63 % of all renal bleeds [1–3]. Of these, malignant lesions account for 30–34 % and benign for 24–33 % of cases. Although cancer of the kidney rarely ruptures spontaneously, it is the commonest tumor to present with RPH

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I. RENAL CAUSES:

A. Systemic:

1. Use of anticoagulants
2. Bleeding disorders such as leukemias, hemophilias etc
3. Polyarteritis nodosa

B. Local:

1. Neoplastic → Benign: such as angiomyolipoma, adenoma
   Malignant → Primary → renal cell Ca, Wilm's tumor, Transitional cell Ca, Sarcoma
   Malignant → Metastatic
2. Vascular → renal artery aneurysm, renal vein thrombosis, arteriovenous malformation and fistula (→ Spontaneous, Acquired), polyarteritis nodosa
3. Inflammatory → Cortical abscess, Nephritis
4. Cysts → Adult polycystic, Other cystic lesions

C. Idiopathic

II. ADRENAL CAUSES:

A. Local:

1. Neoplastic: → Pheochromocytoma, Adenoma, Neuroblastoma, Metastases
2. Cystic lesions

B. Systemic:

1. Medical causes: → Severe sepsis, Acute myocardial infarction
2. Surgical causes: → Burns, Surgery ex. major abdominal or CABG
3. Obstetric etiology: → Pre-eclampsia
4. Drug-induced: → ACTH therapy for^flammatoryJBowel, Anticoagulation
5. Coagulopathy: → Thrombocytopenia, Post-surgery
6. Thrombo-embolic diathesis: → Antiphospholipid antibody syndrome

Fig. 13.1 Common causes of retroperitoneal hemorrhage arising from the kidney or adrenal gland

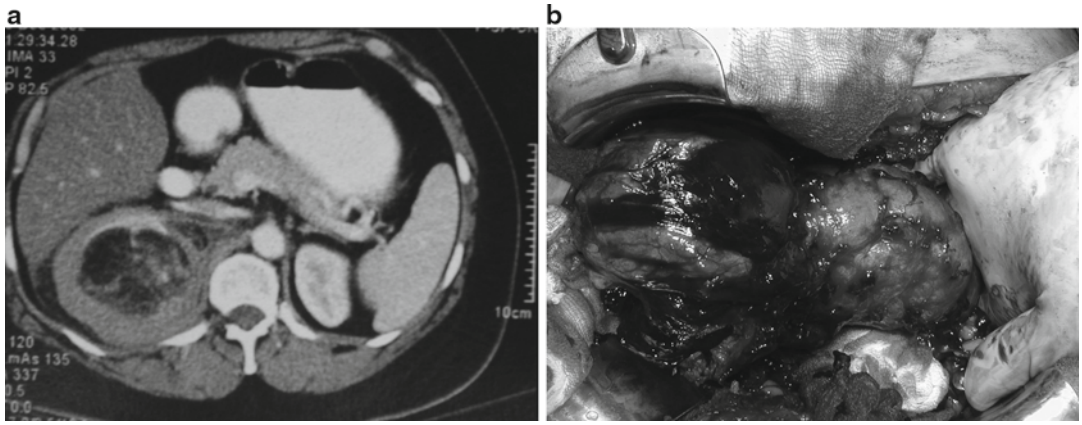

Fig. 13.2 (**a**) CT scan shows large angiomyolipoma of the right kidney with associated perirenal hematoma. (**b**) Intraoperative appearance of same angiomyolipoma showing upper pole lesion with hemorrhage

owing to its relatively common occurrence. Of note, data seems to suggest that the risk of spontaneous renal bleed is independent of the size of the tumor [3]. Other malignant lesions such as transitional cell carcinoma [4], Wilms tumor [5], sarcoma [6], and metastatic lesions [7] have also been reported to present with retroperitoneal bleed.

Benign

Almost all benign tumors causing RPH are angiomyolipomas (AML) (Fig. 13.2a, b) [1–3]. These benign tumors consist of smooth muscle, blood vessels, and fatty tissue in varying proportions and can occur either sporadically (80 %) or as a part of tuberous sclerosis (TS) complex (20 %). TS complex is an autosomal dominant disorder with incomplete penetrance, characterized by mental retardation, epilepsy, and adenoma sebaceum [8, 9]. When AML are associated with tuberous sclerosis, they commonly present earlier (mean age, 30 years), occur with a lesser predilection for the female sex (only twice as common in females compared to males), and are multicentric, larger, more likely to grow, and more prone to rupture (10 % of cases) [9].

The rate of reported bleeding with AML ranges widely. Mouded et al. described a 15 % incidence of rupture in 97 patients with AML [10]. However, Oesterling et al. have shown that 82 % of AML >4 cm on CT are symptomatic and present with RPH in 51 % of cases [11]. Rarely, these tumors have been reported to undergo malignant transformation [12, 13]. Other benign lesions such as adenomas and oncocytomas have also presented with retroperitoneal bleeding in rare cases.

Vascular

Disorders of renal vasculature account for 17–26 % of renal causes of RPH [1–3]. Of these, rupture of renal artery aneurysm is the most serious and can occur at any age with preponderance for fifth to seventh decade of life [14]. Though angiographic studies suggest a 0.3–1 % prevalence of renal artery aneurysm [15], spontaneous rupture is uncommon. However, noncalcified saccular aneurysms [16] and the presence of pregnancy and hypertension [17–19] are believed to increase the risk of spontaneous rupture. When rupture is associated with pregnancy, a mortality rate of 80 % has been reported [14].

Polyarteritis nodosa is a systemic condition characterized by deposition of immune complexes within the media of small- and medium-sized arteries that lead to progressive weakness of the arterial wall and resultant aneurysm formation. Rupture of these aneurysms is responsible for approximately 12 % of RPHs in some series

[1–3]. Other vascular causes such as renal infarction, renal vein thrombosis, and congenital arteriovenous malformations have also been described to present with RPH [20].

Inflammatory/Infectious

Inflammatory lesions such as severe pyelonephritis, cortical abscesses, and xanthogranulomatous pyelonephritis (XGP) can present with RPH and account for 2.4–10 % of cases [3, 21].

Cystic

Hemorrhagic rupture of cysts has been reported in autosomal dominant polycystic kidney disease (ADPKD) as well as the acquired cysts of end-stage renal disease (2–3 % of reported cysts) [22, 23]. Hypertension, bleeding tendency of uremia, and use of anticoagulants during hemodialysis predispose to the development of RPH in these cases [23–25]. Bleeding into a simple renal cyst with rupture has also been described and is commonly secondary due to a coagulation defect, a ruptured cyst wall [26], or trauma (Fig. 13.3).

Bleeding Disorders

Bleeding associated with hemophilia and hematological malignancy can also present with bleeding into the retroperitoneal space and it is essential to rule out these conditions in any case of RPH. While the history of hemophilia is usually known by the patient, diligence in diagnosing other causes of bleeding diathesis such as leukemia may be required. Systemic sequelae of generalized bleeding and history of petechia, easy bruisability, hemarthrosis, or other signs of inappropriate bleeding may be elicited in these patients. Patients on anticoagulants or with an acquired bleeding diathesis may also present with RPH with an incidence of 4.3–6.6 % for heparin and 0.1–0.6 % for warfarin [27–30]. A recent study examined patients presenting with spontaneous retroperitoneal hematoma and identified patients with combined anticoagulation and antiplatelet therapy more often requiring ICU admission and longer ICU stays than patients on anticoagulation therapy alone [31].

Other

Perirenal hematomas have also been described following renal biopsies (Fig. 13.4) (60–85 % incidence demonstrated in follow-up CT scan) [32, 33] and occur independent of presence of coagulopathy, clinical signs of bleeding, fall in hemoglobin levels, or performance of the procedure by an experienced person [32]. Follow-up CT scans in these patients have, however, shown a spontaneous resolution in the hematomas in the majority of instances.

Idiopathic

Uncommonly, in 6.7 % of cases, no cause for RPH is identifiable in the kidney [3].

Adrenal Causes of RPH

Adrenal hemorrhage is a heterogeneous entity that occurs in a wide variety of clinical conditions and is infrequently diagnosed when the patient is alive. It has been reported in 0.14–1.8 % of autopsy studies, though the incidence is higher in critically ill patients [34]. The exact mechanism of adrenal hemorrhage in a stressed adrenal is not known, but interplay of various factors may be responsible. Of these, increased ACTH secretion with an increase in adrenal vascularity and adrenal cortical necrosis, adrenal venoconstriction with resultant stasis and possible adrenal venous thrombosis, and associated coagulopathy may play a role in its development. The common causes for hemorrhage in a stressed adrenal are shown in Fig. 13.1.

Systemic Causes

These conditions commonly lead to bilateral massive adrenal hemorrhage due an overworked

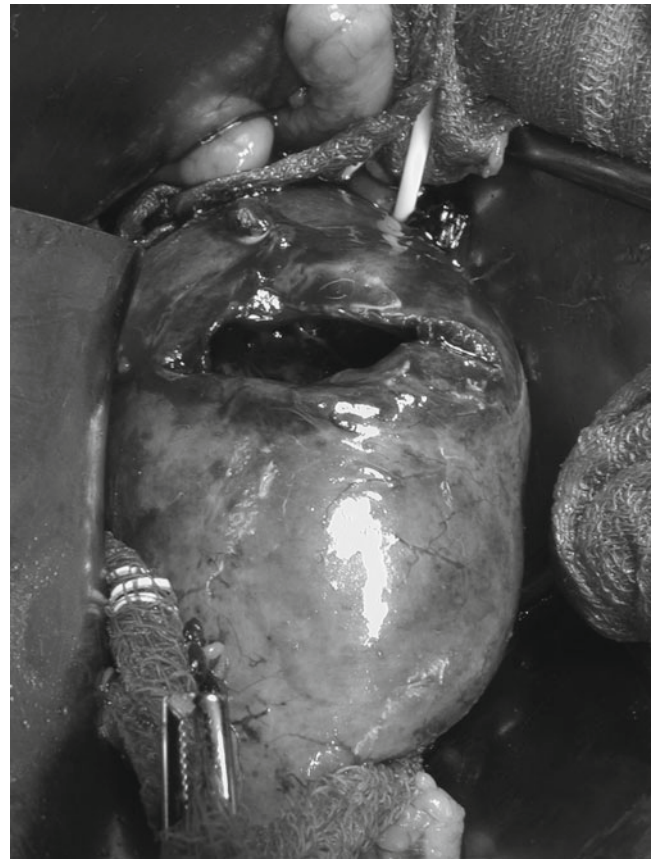

Fig. 13.3 Intraoperative appearance of a ruptured renal cyst

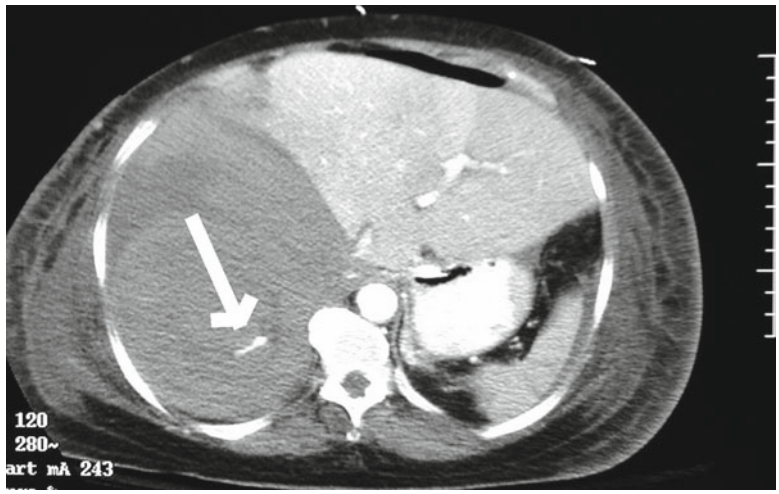

Fig. 13.4 CT scan appearance of RPH following biopsy of the kidney. Note acute extravasation of the contrast denoting brisk bleeding

stressed adrenal. As shown in Fig. 13.1, they can result from a variety of causes ranging from severe sepsis and acute myocardial infarction to burns, trauma, and obstetric causes.

Neoplastic

Neoplasm of the adrenal gland is the most common cause of unilateral adrenal hemorrhage.

Pheochromocytoma is the most frequently encountered adrenal tumor to present with RPH. Other causes such as adrenal adenoma [20], adrenal cyst [35], adrenal myelolipoma [36–38], adrenocortical adenoma [38, 39], and adrenal gland metastases [40] have also been described in the literature.

Pheochromocytomas are catecholamine-producing tumors of neuroectodermal origin that are extraadrenal in 10 %, malignant in 10 %, occur in children in 10 %, and are inherited as autosomal dominant in 10 % of cases. They may be either familial or sporadic. The familial group may be a part of Multiple Endocrine Neoplasia (MEN) type 2 or 3 [41–43], or neuroectodermal dysplasias (consisting of Von Hippel Lindau disease, tuberous sclerosis, Sturge-Weber syndrome, and Von Recklinghausen's syndrome). Pheochromocytomas rarely present with retroperitoneal rupture and have a high mortality if the condition is not diagnosed preoperatively, due to the development of either precipitous hypertension from the release of catecholamines or severe hypotension from blood loss and contracted blood volume secondary to chronically elevated catecholamines. The hemorrhage may be precipitated by indiscriminate use of alpha-blockers that can cause vasoconstriction with resultant necrosis of the gland and hemorrhage.

Adrenal myelolipoma is a benign tumor that consists of a mixture of fatty tissue, myeloid elements, and lymphocytes and has a strong association with hypertension, obesity, and chronic disease. Rupture is rare and is described only in case reports [36–38].

Brisk Hematuria

Brisk hematuria can result from rapid and extensive blood loss into the upper urinary tract. All the lesions described above can lead to hematuria if the lesion communicates with the renal calyces, although this is uncommon. Herein, we describe two rare but clinically important causes of brisk hematuria.

Ureteroarterial Fistula

Ureteroarterial fistulas are an uncommon, but potentially lethal cause of brisk hematuria with a reported mortality of approximately 34–40 % [44–47]. Often the diagnosis is made at postmortem examination. Fistulous communication commonly occurs in the region where the ureter crosses the iliac artery at the pelvic brim [48]. The kidney and ureter proximal to the fistula are commonly obstructed (with resultant hydroureter and hydronephrosis) due to fibrosis of the ureter in the region of the fistula.

Predisposing factors are many. Among them, prior, long-standing ureteral stents account for the majority of cases. The advent of softer stents has led to a decrease in stent erosion, although coincident factors such as prior surgery, irradiation, or arterial pathology such as mycotic aneurysm may still lead to pressure necrosis of the ureter from chronic indwelling stents. Another cause of ureteroarterial fistula is presence of vascular disease or vascular graft surgery. Spontaneous rupture of iliac artery aneurysms into the ureter has been reported, probably secondary to pressure necrosis of the adherent, fixed ureter (to the aneurysm) from the chronic pulsations of the aneurysm [49–51]. Similarly, the combination of a devascularized, compromised ureteric wall (resulting from dissection during arterial graft surgery) and fixation of the ureter to the site of the arterial graft can predispose to pressure necrosis of the ureter and subsequent fistula formation [52]. Finally, prior genitourinary/pelvic surgery and radiation account for the remaining cases of ureteroarterial fistulas that have been reported in the literature.

Arteriovenous Malformation and Fistula

Rarely, A-V malformations of the kidney may present with massive hematuria. Etiologically, these lesions are of two types—spontaneous or acquired. Acquired A-V fistulas are more common, may be secondary to surgery (partial or total nephrectomy, percutaneous renal surgery)

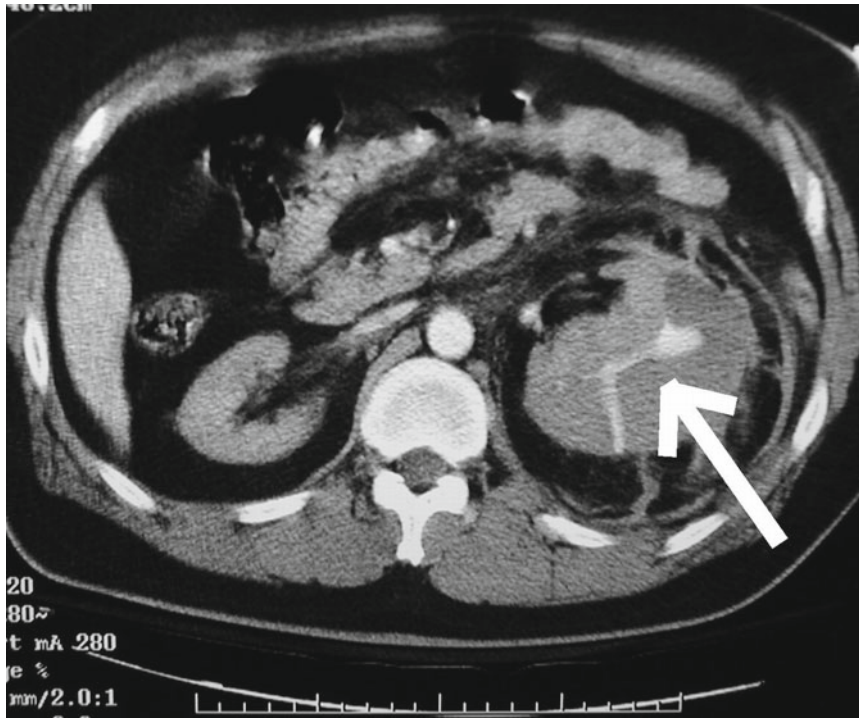

Fig. 13.5 CT scan showing renal arteriovenous malformation (AVM) secondary to renal biopsy

[53–55], renal biopsy (Fig. 13.5) [56–59], trauma [60, 61], renal tumors, or inflammatory renal pathology and may present from 3 weeks to 26 years following the original injury.

Spontaneous A-V fistulas are rarer (only 110 cases have been described in literature) [62] and are of two types, congenital and idiopathic, based on their appearance. Congenital A-V fistulas are classically cirsoid in appearance (a tangle of small-diameter tortuous vessels with multiple variceal A-V communications). The subepithelial location of these lesions accounts for a common presentation of hematuria in these patients (75 %). On the other hand, idiopathic A-V malformations are characterized by one or more large A-V communications, leading to an aneurysmal appearance on pathology. Hematuria occurs in about 35 % of these patients and hypertension and congestive cardiac failure are more common presentations due to renal ischemia and circulatory overload (secondary to the larger size of the Arteriovenous Fistula (AVF)) [62].

Clinical Presentation

Retroperitoneal Hemorrhage

Establishment of preoperative diagnosis of RPH is a diagnostic challenge because it has variable etiologies and may often present with nonspecific signs and symptoms that are difficult to interpret clinically. Therefore, a high index of clinical suspicion is required to diagnose this condition and treat it aggressively.

The presentation is usually acute, although delayed presentation has been described. Patients present with acute onset of pain in the flank or in the general abdomen that is continuous, of increasing severity, and may be associated with nausea and vomiting. There may also be a history of hematuria if the renal parenchyma has ruptured. Examination may reveal signs of hypovolemia such as pallor, tachycardia, and in extreme cases, signs of circulatory collapse with cold clammy skin, thready pulse, and hypotension.

Abdominal examination may reveal bruising in the loin, abdomen, or groin. There may be associated abdominal tenderness, guarding, distension, and hypoactive bowel sounds. An abdominal mass may also be palpable on occasion. RPH is a leading cause of abdominal compartment syndrome, where the expanding hematoma causes an excessive increase in intra-abdominal pressure and compression of the abdominal contents [63]. Rarely, patients with RPH have presented with femoral/lumbar/obturator neuropathy due to the expanding hematoma [64–67]. Occasionally, this condition may present in pregnant patients either due to rupture of renal angiomyolipoma or renal artery aneurysm, or due to adrenal hemorrhage secondary to preeclampsia.

Patients with angiomyolipoma may have stigmata of tuberous sclerosis complex, whereas patients with polyarteritis nodosa may have a history of myalgia, gastrointestinal complaints, low-grade fever, and weight loss. Patients with inflammatory conditions (such as renal abscess/nephritis) may be febrile and demonstrate signs of underlying disease. Patients with cystic disease may present with a diagnosis of the condition (for example, history of ADPKD or renal failure on dialysis).

Patients with adrenal hemorrhage due to systemic causes are difficult to diagnose as they may present with nonspecific signs and the clinical picture is obscured by other coexisting conditions in a critically ill patient. These patients may present with minimal abdominal signs and symptoms, but may occasionally complain of abdominal pain and backache. Usually adrenal hemorrhage is associated with adrenal insufficiency characterized by altered sensorium, fever, lethargy, hypotension unresponsive to routine fluid resuscitation, leukocytosis, hyponatremia, hyperkalemia, increased blood urea nitrogen with a normal creatinine.

Patients with pheochromocytoma may occasionally present with a history of headaches and hypertension and other signs such as café-au-lait spots or subcutaneous nodules of Von Recklinghausen's syndrome. Patients with pheochromocytomas have also been reported to present with pulmonary edema and respiratory distress. Patients with functioning adrenocortical adenomas may have evidence of Cushing's syndrome [20].

Since patients taking anticoagulants or with bleeding disorders can present with RPH it is important to rule out these conditions in the evaluation of the patient with retroperitoneal bleeding. Laboratory evaluation of routine blood tests may warn the physician of ongoing blood loss with falling hemoglobin and hematocrit, leukocytosis and a rising blood urea nitrogen. Urine analysis may show evidence of hematuria.

Brisk Hematuria

Ureteroarterial Fistula

Patients with ureteroarterial fistulas may present with a history of prior radiation, pelvic or vascular surgery, or long-standing indwelling stents. As these conditions are very uncommon, they are rarely considered in the differential diagnosis of hematuria. Often, there may be a history of mild hematuria ranging from 3 weeks to 3 months that precedes the onset of massive hematuria [49]. A high index of clinical suspicion combined with a history of predisposing factors should alert the physician of this potentially lethal condition.

Arteriovenous Malformation

Patients with arteriovenous malformation (AVM)/AVF may have a history of prior renal biopsy, renal surgery, or trauma. Depending on severity of bleeding and size of the AVM, these patients present with recurrent hematuria, lumbar pain due to clot colic, severe anemia, hypertension, and cardiac failure. Abdominal examination may reveal an abdominal bruit or thrill.

Brisk hematuria requires the same laboratory evaluation as described above for RPH.

Sequelae of RPH

Failure to diagnose and promptly treat RPH can lead to serious early consequences such as hypovolemic shock, multisystem organ failure, coagulopathy, and death. Potential late complications include retroperitoneal fibrosis and Page

kidney. Originally described by Page in 1939, this syndrome consists of development of renin-mediated hypertension secondary to the formation of thick dense scar tissue around the kidney [68]. Rarely, this condition has been described secondary to perirenal hematomas following renal surgery or trauma [69]. Transient perirenal hematomas that produce hypertension have also been described [70]. Given the great number of renal surgeries that are performed, this form of hypertension should be considered as a rare phenomenon and has been mentioned to make the urologist aware of this possibility.

Diagnostic Investigations

Retroperitoneal Hemorrhage

The aim of diagnostic investigations is to identify RPH, evaluate its severity, and determine the probable cause of the condition.

Imaging Studies

CT scan of the abdomen is the investigation of choice to diagnose or rule out RPH. A meta-analysis of patients with RPH has demonstrated that CT scan is 100 % sensitive in diagnosing this entity [3, 49]. Though the specificity for detecting an underlying renal mass is only moderate (0.56), it has a higher sensitivity and specificity compared to an abdominal ultrasound. To maximize the diagnostic accuracy of CT scan, Bosniak recommended scanning before and after intravenous contrast and taking 5 mm thick sections. As described later, Bosniak and Belville recommended serial CT scans for evaluating indeterminate cause of RPH if the patient's condition is stable [71, 72]. This approach yields a diagnostic accuracy of 92 %. CT is also useful in detecting and differentiating renal cell carcinoma from other causes such as angiomyolipoma, transitional cell carcinoma, adrenal hemorrhage, bleeding due to anticoagulants, and bleeding from cysts [71, 72]. Furthermore, it is easily available at most centers, rapid, noninvasive, and gives additional helpful diagnostic information. Lesions such as angiomyolipomas will be suggested by the presence of fat within the lesion (Hounsfield Units < −40), oncocytomas may have the central stellate scar, renal cell carcinoma can be staged, and metastases can be diagnosed. CT scan has also been shown to be useful in determining the size of the hematoma, which some preliminary studies indicate may be useful in estimating blood loss [73]. A volumetric study evaluating the effect of RPH size as measured by CT identified a RPH volume of 1,600 cc or greater of being predictive of delayed mass effect and increased 6-month mortality [74].

MRI is indicated if CT scan is unavailable or CT scan findings are equivocal (for example to differentiate angiomyolipoma from renal cell cancer). MRI can also be used for planning of appropriate surgical approach for some renal lesions, or for managing pregnant patients.

Angiography is not a primary diagnostic modality for RPH. However, it is useful for the diagnosis of vascular diseases associated with spontaneous renal hemorrhage, such as polyarteritis nodosa, A-V malformation and renal artery aneurysm, and when emergency embolization is planned.

Other Studies

Plain X-ray of the abdomen is commonly used to assess a patient of acute abdomen, but is not sensitive in diagnosing RPH. However, it may provide indirect clues to the diagnosis such as loss of psoas shadow, calcification over the kidney (suggestive of renal mass or aneurysm), or enlarged or abnormal contour of the renal shadow.

Once the diagnosis of RPH has been established, it may be necessary to differentiate various etiologies as this may decide the further course of action (example: surgical vs. nonsurgical, type of surgical procedure, etc.). Other studies may be indicated to help diagnose conditions such as pheochromocytomas, Cushing's syndrome or bleeding disorders.

Brisk Hematuria

Investigations for Ureteroarterial Fistulas

Patients with ureteroarterial fistulas often will have undergone investigations such as cystoscopy or CT-IVP to evaluate hematuria. If clinical

suspicion suggests this etiology, arteriography and retrograde ureterography are the most sensitive investigations to diagnose ureteroarterial fistula. However, they are successful in diagnosing the condition in only 41 % [44, 47, 75] and 45 % [47] of cases, respectively. CT scan of the abdomen may demonstrate presence of hydronephrosis and probable hematoma in the region of the ureter. Recently, Vandersteen et al. have used provoked arteriography to establish the diagnosis of ureteroarterial fistula [44]. They perform an initial standard arteriogram and if that is inconclusive, the indwelling ureteral stent is removed over a guide wire (if the ureter is previously unstented, it is accessed either in an antegrade or retrograde manner with a guide wire). If no bleeding occurs, a deflated angioplasty balloon is introduced over the guide wire and alternately advanced and withdrawn within the ureter to provoke the hemorrhage. An arteriogram is then performed to demonstrate the ureteroarterial fistula. The authors have claimed 100 % sensitivity in diagnosing the condition with this approach. The additional advantage of this approach is that a definitive arteriographic embolization can be attempted if the diagnosis is established. It is important to keep the operating room available and ready in case these measures are not successful in controlling the hemorrhage.

Investigations for Arteriovenous Malformation and Fistula

As with ureteroarterial fistula, often patients with AVM/AVF will have undergone investigations for the investigation of hematuria. Findings on CT-IVP such as an irregular filling defect or compression of the renal pelvis by dilated vessels may serve to warn of an underlying AVM and should warrant further investigations. Recently, duplex and color ultrasound has been also found to be useful in diagnosing the condition [76–78]. A-V malformations have also been demonstrated after an immediate postinjection CT scan with contrast, which shows the vascular luminal nature of the fistula, dilatation of the renal vein, and early opacification of the IVC. MRI has also been used to demonstrate these lesions [79–81]. However, angiography is the diagnostic procedure of choice as it helps define the type and anatomy (site and blood supply) of A-V fistula. In the cirsoid type, the presence of tortuous, dilated, and multichanelled vessels is associated with an early filling of the renal veins, whereas the idiopathic type is characterized by aneurysmal dilatation of the artery and vein and an early passage of the contrast medium into the renal vein, IVC, or even into the ovarian/gonadal vein [62, 82]. The arteriographic appearance in the acquired AVM/AVF is similar to the idiopathic AVM/AVF.

Management

Principles of management are predicated on resuscitation of the patient, establishment of the diagnosis, if possible, and definitive treatment.

Resuscitation of the Patient

Depending upon the severity and acuity of bleeding, patients may present with hemorrhagic shock due to the depletion of intravascular volume. Therefore, it is important to initiate resuscitative measures immediately. Restoration of intravascular volume can be achieved by administration of intravenous fluids (crystalloids/colloids) by means of a large bore intravenous canula. Blood transfusion for correction of anemia may also be needed. As resuscitative measures are initiated, baseline laboratory studies need to be performed to determine severity of hemorrhage (hemoglobin, hematocrit), renal function (blood urea nitrogen, serum creatinine), and rule out bleeding diathesis (bleeding and clotting times, prothrombin time, International Normalized Ratio (INR), activated partial thromboplastin time, platelet count, etc.) and for cross-matching of blood.

Establishment of Diagnosis

Once the patient is adequately resuscitated, an attempt must be made to establish the diagnosis of RPH and determine the etiology of RPH. If the patient continues to have signs of exsanguinating hemorrhage in spite of resuscitative measures, it may not be possible to spend time trying to establish the diagnosis and the patient may need surgical or angiographic intervention (Fig. 13.6) urgently to try and control the bleeding.

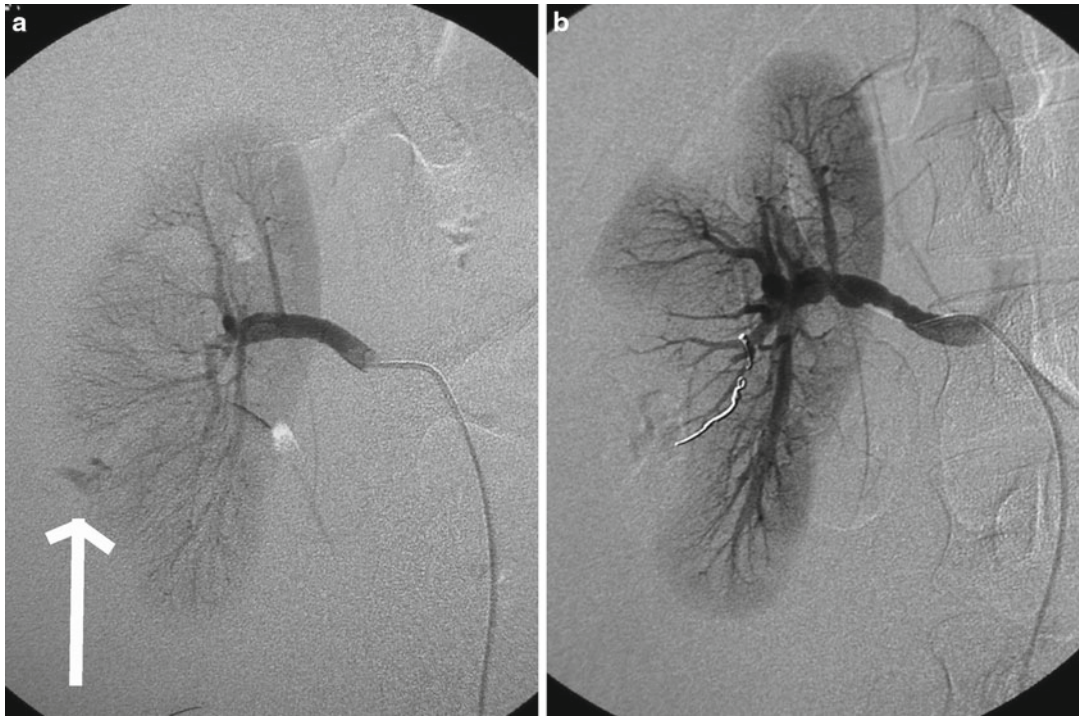

Fig. 13.6 (**a**) Angiogram showing active bleeding with "blush" of escaping blood/contrast (*arrow*). (**b**) Angiogram of the AVM after coil embolization

CT scan of the abdomen is the investigation of choice to diagnose RPH rapidly and with a high level of accuracy in those stable enough to undergo it. Further investigations may be indicated if the diagnosis is uncertain and the patient is stable enough.

Definitive Treatment

Retroperitoneal Hemorrhage

Definitive treatment is determined by the underlying cause of RPH, the patient's general condition, and urgency of the situation. Conservative management is indicated when the cause of RPH is determined to be secondary to the presence of a bleeding diathesis. Use of fresh frozen plasma, clotting factors, platelets, and protamine may be indicated to correct the underlying abnormality.

If the bleeding is suspected to be due to adrenal crisis in a critically ill patient, prompt initiation of steroid therapy may be indicated even prior to confirmation of the diagnosis. In such cases, the bleeding is commonly bilateral, and aggressive supportive therapy along with steroid replacement and correction of the underlying cause of the condition may help salvage the patient.

On the other hand, unilateral adrenal hemorrhage may be secondary to an adrenal tumor. Since pheochromocytoma is the commonest cause of adrenal tumor and is associated with a high intraoperative mortality if undiagnosed prior to surgery, it is imperative to diagnose it and initiate appropriate measures preoperatively. Aggressive fluid resuscitation and blood pressure management are necessary in these patients.

When the cause of RPH is secondary to a renal tumor, it is essential to differentiate angiomyolipoma from other malignant tumors. CT scan is useful in diagnosing the lesion preoperatively, but in the presence of uncertainty, it may be necessary to supplement CT with MRI or even intraoperative biopsy of the lesion. Preserving renal function is an important consideration in these patients especially in the presence of the TS complex, where the tumors may be multiple and bilateral. Angiographic embolization may be an option in

the management of renal bleeding, especially in patients with poor renal reserve and who are poor surgical candidates. The advantages of angiographic embolization of angiomyolipoma include the preservation of renal parenchyma and ability to selectively embolize bleeding vessels, thus circumventing the need for surgery. Nelson and Sanda [83] summarized the results of angiographic embolization of angiomyolipomas in 76 patients and showed a 10 % incidence of complications (5 % abscesses, 3 % pleural effusion), 17 % incidence of recurrent symptoms or hemorrhage, 14 % incidence of repeat embolization, and a 16 % incidence of surgery. Eighty-five percent of patients experienced a postembolization syndrome consisting of flank pain, fever, leucocytosis, and nausea. Treatment consisted of administration of antipyretics, antiemetics, and analgesics, and most patients recovered in 2–5 days [84]. A recent study with long-term follow-up (5 years) of patients receiving selective arterial angioembolization of bleeding AML lesions reported 94 % freedom from surgical treatment and disease-specific survival of 100 % [85]. Surgical options include enucleation of the tumor, partial nephrectomy, and complete nephrectomy. Complete nephrectomy is usually indicated for a tumor located near the hilum, a tumor sufficiently large to cause a greater risk for partial than total nephrectomy, suspicion of malignancy, associated RCC, or inability to control bleeding by less conservative means [83].

Where the cause is secondary to a ruptured renal artery aneurysm, emergency nephrectomy is usually required as renal artery aneurysm commonly extends into the renal hilum making conservative surgery impractical. Rarely, renal arterial bleeding may be secondary to a congenital arteriovenous malformation or from aneurysm of a segmental artery, in which case, angiographic embolization/partial nephrectomy is an option [14].

RPH secondary to polyarteritis nodosa should be managed by conservative means whenever possible as often this condition is associated with renal dysfunction. Treatment options include corticosteroid and immunosuppressive therapy [86], selective arterial embolization [87], and partial nephrectomy. Spontaneous rupture of renal cysts is rare, though it may occur after trauma. Treatment is conservative or operative just as in other cases of RPH secondary to a renal etiology.

In a small percentage of cases, it is not possible to demonstrate the exact cause of RPH in the kidney in spite of thorough investigation. Kendall et al. needed to perform nephrectomy in 7 patients with an inconclusive preoperative diagnosis [88]. They were able to demonstrate a small carcinoma in 5 of the 7 cases and concluded that imaging studies may not demonstrate smaller cancerous lesions within the kidney. Bosniak and Belville recommended detailed evaluation of the imaging studies and serial scanning to help identify the cause of RPH in these patients. They suggested that this approach did not increase the risk to the patient and avoided unnecessary removal of normal kidneys [71, 72]. In such cases where RPH is present but the kidney appears largely normal, it may also be necessary to rule out other nonurologic causes of RPH (example, acute pancreatitis).

Brisk Hematuria

Ureteroarterial Fistula

Since the cause of the ureteroarterial fistula is the connection between the ureter and the iliac artery, the definitive management should be directed towards management of both the ureteric as well as the arterial lesion. The most common urological procedures that have been performed in the past are nephrectomy and ureteral ligation [47, 89, 90] followed by autotransplantation, renal embolization, or renal irradiation [90, 91]. The disadvantages of these approaches are that they do not address the underlying ureteric pathology and are associated with an increased morbidity. It is not surprising therefore, that some of these procedures have been associated with massive bleeding from the ureteral stump in the postoperative period [45, 90].

No consensus exists on the vascular management and the most common vascular interventions include primary vascular repair [50, 92], iliac artery ligation [93–95] with or without femoral

bypass, and placement of interposition graft. Complications such as distal limb gangrene requiring amputation and operative death have been reported following these procedures.

A review of literature has shown that an aggressive multidisciplinary approach involving urology, radiology, and vascular surgery can successfully bring down the mortality of ureteroarterial fistula from 63 to 31 % [49]. Vandersteen et al. were able to successfully salvage all renal units and achieved 0 % mortality in 4 patients with 5 ureteroarterial fistulas with such an approach [44]. Based on their experience, they recommended provocative angiography to diagnose the fistula. In the presence of ureteroarterial fistula, they utilized arterial embolization to control the hemorrhage. Following the control of arterial bleeding, ureteral stents may be routinely and successfully replaced to manage the ureteral obstruction. In the event that the patients developed distal limb ischemia, they recommended extra-anatomic bypass (femoro-femoral) to correct the problem.

In cases where embolization is unsuccessful in controlling the hemorrhage, or if the patient undergoes surgery as the primary approach (severe shock or condition diagnosed on table), ligation of the iliac artery is a suitable way of controlling the arterial hemorrhage. This approach is usually well tolerated without further reconstruction if there is no distal arterial disease. In the event that the patient has distal arterial disease, an extra-anatomic bypass is the fastest and the safest operative procedure to correct it. Direct in-situ arterial repair locally (at the site of fistula) is generally not recommended due to associated local sepsis and contamination, as well as the potential for vessel weakness secondary to irradiation, aneurismal dilatation, or mycotic aneurysm [49].

With the advent of endovascular treatment of vascular disease, the role of endovascular treatment for ureteroarterial fistulas is in evolution. A recent series by Fox et al. [96] compared the long-term outcomes of endovascular treatment of this disease with conventional open surgery. Their series examined the long-term outcomes in 19 patients with 20 ureteroarterial fistulas. The authors found that at a mean follow-up of 15.5 months the endovascular stenting of this pathology resulted in an 85 % success rate. The authors also proposed that endovascular treatment of this disease should not be reserved for patients who are judged to be poor surgical candidates, but should be an integral part of the treatment algorithm for all patients with ureteroarterial fistula.

The aim of urologic management is to try and salvage renal function wherever possible. Once arterial control is obtained, attention is focused towards correction of the urologic lesion. Various treatment options described include "no further treatment" [97, 98], nephrectomy and/or nephroureterectomies (in presence of nonfunctioning kidneys), and procedures to divert urine flow away from the fistula (transuretero-ureterostomy, uretero-ureterostomy, percutaneous nephrostomy, and ligation of the ureter) [49, 99, 100].

Arteriovenous Malformation/Fistula

Several case reports describe nonoperative observation of AVM since some AVM are known to disappear over a period of time. For example, although 1–18 % of patients have been reported to develop an AVM following renal biopsy, nearly 80 % of these disappear over a period of many months [101]. Observation is justified in asymptomatic or peripherally located small AVM or where symptoms are adequately controlled by medical means. In the presence of significant symptoms, however, treatment is indicated.

The aim of treatment is to salvage renal function. Treatment options include arteriographic embolization [102–105], excision of the lesion, partial or total nephrectomy [82], ligation of fistula [106], alcohol injection of the fistula [107], endofistulorrhaphy [108], and endovascular management of the fistula [109, 110].

Conclusions

Spontaneous RPH has multiple etiologies, may be life threatening, and requires a high index of clinical suspicion for detection. CT scan is an accurate and sensitive investigation to diagnose the condition. If CT scan fails to determine the cause of the hemorrhage, additional investigations

such as MRI and angiography may help clinch the diagnosis in patients who are stable. It is equally important to identify medical causes for RPH such as bleeding disorders (iatrogenic or pathological) or adrenal crisis in the appropriate patients. If no cause of RPH is detectable in spite of various investigative procedures, serial CT scans in a stable patient are a safe and viable approach to ensure that a small RCC or other important investigation is not missed.

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Hemorrhagic Cystitis

14

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Introduction

Hemorrhagic cystitis (HC) is a common urological disorder, presenting in 6.5 % of patients following pelvic radiation therapy and up to 25 % of patients receiving alkylating chemotherapeutic agents. HC can be devastating, with high morbidity and mortality despite aggressive interventions [1]. Massive urothelial hemorrhage may involve both upper and lower urinary tracts [2], leading to acute renal failure that requires emergent urological interventions.

HC is classified by five grades [3]:
Grade 1: Single minor bleeding
Grade 2: Repeated minor bleeding
Grade 3: Inpatient medical treatment needed
Grade 4: Inpatient surgical treatment needed
Grade 5: Death

HC often does not proceed in a stepwise fashion through the grading scale. Although most patients initially present with minor bleeding episodes, the initial presentation may be massive macroscopic hematuria with clot retention that may require clot evacuation and blood transfusion.

For clinical trials data analysis, the Radiation Therapy Oncology Group (RTOG) based in the United States and the European Organization for Research and Treatment of Cancer (EORTC) based in Belgium have classified radiation treatment-related genitourinary morbidity. Table 14.1 summarizes the RTOG morbidity scoring scheme for acute radiation genitourinary morbidity and RTOG/EORTC morbidity scoring scheme for late radiation bladder complications. Acute morbidity criteria are used to grade radiation treatment-related toxicity from the first day of radiation therapy for a total of 90 days. Any radiation treatment-related morbidity that occurs after the initial 90 days will be scored using the RTOG/EORTC criteria.

Etiology and Risk Factors

Among the risk factors for HC presented in Table 14.2, previous pelvic irradiation and chemotherapeutic drugs like cyclophosphamide are the most common causes of HC. In a randomized Danish study, up to 25 % of 118 patients with early ovarian cancer developed HC after external beam radiation and cyclophosphamide treatment [4].

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Table 14.1 Classification adapted from RTOG scoring criteria (acute radiation genitourinary morbidity) and RTOG/EORTC late radiation morbidity scheme (late radiation bladder morbidity)[a]

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
Acute morbidity (RTOG)	Frequency and nocturia twice pretreatment habit	Frequency and nocturia less than once per hour	Frequency and nocturia at least once per hour	Hematuria requiring transfusion	Death from uncontrolled toxicity
	Dysuria and urgency without need for medication	Dysuria, urgency, and bladder spasm requiring local anesthetic	Dysuria, pelvic pain, and bladder spasm requiring regular, frequent narcotics	Acute bladder outlet obstruction not owing to clot passage, ulceration, or necrosis	
			Gross hematuria with or without clot passage		
Late morbidity (RTOG/EORTC)	Slight epithelial atrophy	Generalized telangiectasia	Severe generalized telangiectasia and petechiae	Bladder necrosis	Death from uncontrolled hematuria
	Minor telangiectasia	Moderate frequency		Bladder capacity <100 cm^3	
	Microscopic hematuria	Intermittent macroscopic hematuria	Severe frequency, dysuria	Severe hemorrhagic cystitis	
			Frequent hematuria		
			Bladder capacity <150 cc		

RTOG Radiation Therapy Oncology Group; *EORTC* European Organization for Research and Treatment of Cancer
[a]Grade 0 refers to no treatment-related morbidity

Table 14.2 Common causes of hemorrhagic cystitis

Pelvic irradiation	External beam pelvic radiation
	Interstitial radioactive seed implantation for prostate cancer
Chemotherapeutic agents	Cyclophosphamide
	Ifosfamide
	Busulfan
Viral infections	BK virus
	Adenovirus
	Cytomegalovirus

Radiation-Induced HC

Radiation therapy induces chronic fibrosis and progressive endarteritis. When the urothelium is within the radiation field, the end result of such chronic scarring is urothelial sloughing and bleeding. In the treatment of prostatic, bladder, or cervical cancer, the bladder mucosa is primarily at risk. The onset of radiation effects may appear more than 10 years following pelvic irradiation [5]. Patients who are at high risk include those with wide radiation fields and a higher total radiation dose. There is no reliable predictor as to which patient will be affected or when the episodes of HC will occur. Genetic work suggests that some individuals may be more susceptible to radiation-associated bleeding due to differing gene expression profiles [6].

With the acceptance of contemporary conformal radiation delivery and interstitial therapy, the incidence of radiation-induced HC is expected to decline.

Chemotherapeutic Agent-Induced HC

HC is commonly associated with the use of chemotherapeutic agents in both cancer and nonneoplastic diseases. Most published literature on HC and its prevention focuses on bone marrow transplantation. The most commonly implicated agents are the alkylating oxazaphosphorine agents, which include cyclophosphamide [7–9] and ifosfamide [10, 11]. Bladder mucosal hemorrhage is caused by acrolein, the toxic metabolite of the alkylating agents. Acrolein toxicity may result in life-threatening exsanguination and disseminated intravascular coagulopathy [12].

A retrospective review of complications in 447 bone marrow transplant patients demonstrated that bleeding episodes are associated with prolonged thrombocytopenia, graft-vs.-host disease, and cyclophosphamide regimes [13]. The effects of these agents are dose-dependent but independent of patients' age [11, 14].

Other cyclophosphamide-induced episodes of HC have been reported in the treatment of Wegener's granulomatosis [15, 16], Ewing's sarcoma [17], advanced nonsmall cell lung cancer [18], paratesticular rhabdomyosarcoma [19], and malignant brain tumors [20].

Contemporary chemotherapeutic agents such as busulfan [21] and temozolomide [22] have a lower incidence of HC.

Viral Infection-Induced HC

Superimposed infections often complicate clinical outcome in immunocompromised hosts after bone marrow or solid organ transplantations. Although viral-associated HC was uncommon in the past, the emerging frequency of viral infections from BK virus [23–25], cytomegalovirus [26], and adenovirus [27, 28] is a cause for concern.

BK virus is a human polyomavirus related to the papovavirus family. After primary infection, the BK virus stays dormant in renal parenchyma until reactivation in immunocompromised hosts [29]. This is one of the most common causes of viral-associated HC after bone marrow and renal transplantations. Using real-time quantitative polymerase chain reaction, BK viruria is related to the occurrence and severity of HC after bone marrow transplantation, without detectable increase in BK viremia [30]. Italian researchers using deoxyribonucleic acid (DNA) hybridization assay and polymerase chain reaction analysis also found concurrent urinary shedding of BK virus in prospective cases [31] of HC. This indicates a possible adverse role of direct viral contact on the urothelium with resultant HC.

Adenoviral infection (subtypes 11 and 35), although less common than BK infection, can occur in postrenal transplant recipients as well [32]. Adenoviral-associated HC usually occurs 6 weeks after transplantation, is self-limiting, and

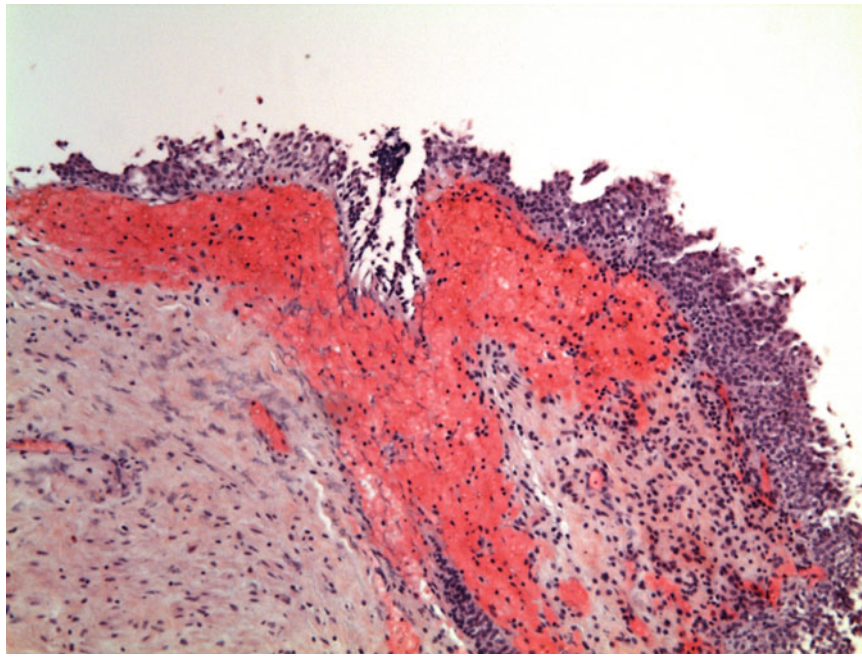

Fig. 14.1 Photomicrograph of the pathologic process of hemorrhagic cystitis

resolves with adequate hydration within 1–2 weeks. The viral load in the posttransplant is not predictive of subsequent HC development [33].

BK virus-associated HC has also been reported in nontransplant patients with human immunodeficiency virus [34].

Miscellaneous Causes of HC

Esoteric causes of HC include penicillin G [35], ischemic necrosis from bladder overdistension in neurogenic bladder [36], and Boon's disease with massive apoptosis and exfoliation of urothelium caused by hypovolemia [37].

Pathology

In HC, mucosal hyperemia is associated with neutrophilic infiltration of the lamina propria, endarteritis, and fibroblastic reactions seen in chronic fibrosis (Fig. 14.1). Nonneoplastic variants may include squamous metaplasia (without cellular atypia or keratinization), cystitis cystica (with eosinophilic liquefaction of benign urothelium in lamina propria, almost similar to von Brunn's nests), cystitis follicularis (with submucosal lymphoid follicles reacting to chronic bacterial infection), or inverted papilloma [38].

Because severe dysplasia, carcinoma in situ, and transitional or squamous cell carcinoma may present with macroscopic hematuria, it is important to exclude malignancies when diagnosing HC. In addition to causing HC, both external beam radiation and cyclophosphamide are associated with an increased risk of bladder cancer development [39].

Clinical Presentation

HC in adult and pediatric patients most commonly occurs in immunosuppressed, oncological, and autoimmune patients. Among transplants, bone marrow transplantation [40, 41] is the most significant contributor. An initial herald bleed may signify mucosal hemorrhage and warrants further investigations with upper tract imaging and cystoscopy to exclude common causes of hematuria.

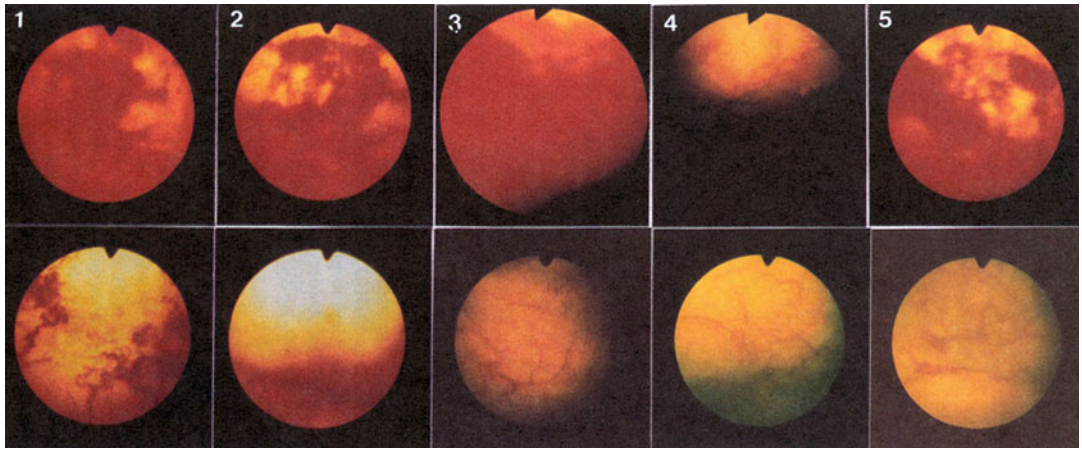

Fig. 14.2 Cytoscopic appearance of the bladder at the time of hemorrhagic cystitis

Quantity and frequency of hematuria are unpredictable. Independent of age, most patients present with a single-episode or recurrent minor bleeding. Less commonly, patients may present with chronic fatigue, syncope, or unexplained anemia.

Patients develop clot retention caused by either continuous profuse bleeding or prior bladder outlet obstruction. In elderly males with prostatic enlargement, higher urinary outflow resistance contributes to reduced clot clearance, resulting in the vicious cycle of increased intravesical blood clot formation. Rarely, hypotension and hypovolemic shock may occur with uncontrolled hematuria.

Investigations

HC presents with macroscopic hematuria, and thus several more common causes of hematuria must be excluded. These include urinary tract infection with inflammatory cystitis, urolithiasis, benign prostatic hypertrophy, transitional cell carcinoma, and aspirin or coumadin ingestion. First-line investigations to be done are urinary bacterial cultures, hematocrit level, and coagulation profile if indicated.

Cystoscopy

Cystoscopy under anesthesia is indicated if the patient has uncontrollable bleeding requiring blood transfusion, persistent clot retention despite bladder irrigation, or repeated episodes of HC (Fig. 14.2). Although it is a minimally invasive procedure, bladder perforation is a potential complication caused by friable bladder tissues. This is especially true in a scarred, contracted irradiated bladder with little compliance to saline distension and instrument manipulation.

Cystoscopy is used as a diagnostic and therapeutic tool for clot evacuation, bladder cauterization, and bladder biopsy to rule out transitional cell carcinoma. Even in patients who receive excessive anticoagulants, up to 18 % of patients in one series were diagnosed with concurrent urinary malignancies [42], justifying the procedure in such cases. After cystoscopic clot evacuation, continuous bladder irrigation is maintained to prevent development of new clots (see below for details of proper technique).

Radiological Imaging

Imaging studies concentrate on exclusion of upper urinary tract malignancies. Cross-sectional imaging with intravenous contrast that include the pyelographic phase, such as CT-IVP, is performed to exclude urothelial tumors. In patients with renal insufficiency, noncontrast imaging modalities such as MRI [43] should be utilized.

An additional advantage of imaging studies is the ability to assess the bladder for clot volume. If identified clots cannot be fully evacuated at the bedside, operative cystoscopic evacuation is indicated.

A report of 12 patients used ultrasonographic features to describe three different types of bladder abnormalities in HC patients after bone marrow transplantation. These types are circumscribed thickening of bladder wall, diffuse thickening of the bladder wall, and intraluminal lobulated bulky mass [44]. Median bleeding duration was longer in patients with intraluminal lobulated bulky mass at 90 days. Although premature, this technique may be a useful noninvasive imaging modality to screen patients for potential future bleeding episodes.

Prophylaxis

Prevention of hemorrhagic episodes in high-risk patients is the most important strategy. Common methods used include use of mesna (sodium-2-mercaptoethansulfonate), intravenous hyperhydration, continuous bladder irrigation, or modification of the chemotherapeutic conditioning regime.

Mesna is a sulfhydryl compound that binds to acrolein metabolites in the urinary tract. It is administered through intravenous or subcutaneous routes and initially had raised interest for widespread applications [45–48]. However, mesna and its metabolites may cause significant vasculitic side effects such as erythroderma, bullous skin lesions, myalgia, fever, and perimyocarditis [49]. Hence, its routine use is superceded by the primary prevention strategies of forced diuresis and bladder irrigation.

During high-dose cyclophosphamide treatment in 303 patients, aggressive hyperhydration with intravenous fluid to maintain urine output above 200 mL/h, coupled with continuous bladder irrigation, showed impressive results with no macroscopic hematuria [50]. Using less-stringent requirements for forced diuresis, hyperhydration and mesna were equally effective in a randomized trial [51].

The most important factor in preventive measures is the dilution or rapid excretion of the chemotherapeutic toxic metabolites. Hyperhydration with intravenous crystalloids and furosemide to maintain hourly urine output of more than 150 mL is recommended as efficacious, cost-effective, and well tolerated [52].

Management

Management of patients depends on the clinical presentation, severity of bleeding, and medical resources available. It is uncommon to see an actively bleeding patient with hemorrhagic shock who requires emergency surgical intervention. Be wary, however, of patients presenting with syncope and clot retention, which may reflect significant hemorrhage and hemodynamic compromise. The volume of blood contained in a distended bladder is often underestimated by less-experienced physicians. Most patients with mild symptoms are managed with the following first-line and second-line therapies.

First-Line Therapy

Minor bleeding usually resolves spontaneously. No medical treatment is needed other than investigations to exclude common causes of hematuria. If bleeding is persistent with clot formation, causing patient distress with urinary retention, immediate manual clot evacuation and bladder irrigation is done through a large-bore transurethral urinary catheter. The success of the bladder irrigation is highly dependent on a thorough and complete manual clot evacuation, using a piston syringe and repeated instillation and aspiration of 0.9 normal saline (NS). The manual clot evacuation is followed by continuous bladder irrigation using 0.9 NS, a large-bore irrigation tubing with drip chamber with a large-bore (e.g., 22–24 Fr) three-way urinary catheter for at least 24 h to ensure removal of residual clot fragments and termination of hematuria.

If bleeding persists despite conservative management, cystoscopy, clot evacuation, and bladder

Fig. 14.3 Hyperbaric oxygen chamber

cauterization are performed. Bladder biopsies should be done concurrently in postradiation patients and in cases of recurrent hematuria of unknown etiology.

Second-Line Therapy

Second-line therapies are indicated for patients with recalcitrant HC without life-threatening hematuria. Several options are discussed and used depending on resource availability, including hyperbaric oxygen therapy, intravesical, and oral agents.

Hyperbaric Oxygen Therapy

With more than 200 monoplace and 20 multiplace hyperbaric chambers throughout North America [53], hyperbaric oxygen (HBO_2) therapy is emerging as an important option for early intervention of HC. By definition, a patient who receives hyperbaric oxygen therapy must receive oxygen within an enclosed chamber with pressurization of 1.4 atm absolute (atm abs) or higher. Currently, established clinical uses of HBO_2 include air embolism, carbon monoxide poisoning, decompression sickness, diabetic foot ulcers, postradiation tissue injuries, and soft tissue necrotizing fasciitis [54].

When placed in an enclosed chamber (Fig. 14.3), pressurized oxygen delivery results in the plasma hypersaturation of dissolved oxygen. Excess plasma oxygenation improves local and regional tissue oxygen supply in tissues with poor oxygenation caused by previous radiation, mechanical, or chemical injuries [55]. This is achieved by the creation of a steep oxygen gradient between the end arterioles and capillaries and the hypoxic tissues that require treatment.

Dissolved oxygen in the plasma diffuses across the capillary bed to improve local tissue oxygenation. Adequate tissue oxygenation will ensure efficient production of adenosine triphosphates (ATPs), as well as other components essential for normal cellular function, resulting in

primary angiogenesis. Neovascularization occurs with capillary ingrowth into hypoxic tissues.

Compared to normobaric oxygen, hyperbaric oxygen provides an eight- to ninefold increase in vascular density in an irradiated rabbit model [56]. In mice models, neovascularization can be seen 5 days after initiation of HBO_2 therapy, even in tissue that is typically nonvascularized (fat) [57]. In irradiated human oral tissues treated for mandibular osteoradionecrosis, HBO_2 therapy resulted in significant increase of transmucosal oxygen tension after only five treatments [58]. It is the synergistic effect of greater molecular oxygen supply and increased vascular density in the hypoxic tissue that allows adequate collagen synthesis and wound repair to occur.

Hyperbaric oxygen therapy successfully resolves hematuria in most postradiation HC [59–64]. HBO_2 is also the only form of therapy that promotes tissue healing. Most hyperbaric oxygen therapy sessions are 90 min. A typical treatment course requires at least 30 daily sessions at 2.36 atm abs pressure. Contraindications for hyperbaric therapy include: emphysema, middle ear dysfunction, congestive heart failure, untreated pneumothorax, and concurrent treatment with cisplatinum, doxorubicin, bleomycin, disulfiram, and mafenide acetate [65].

Potential complications to HBO_2 include claustrophobia, otalgia, barotraumas, and seizures from central nervous system toxicity. To reduce central nervous system toxicity, at least three to four "air breaks" are given during each session. Air breaks are 5–10 min each of normal air breathing. If seizures occur during treatment, conversion to normal air breathing typically resolves the symptom.

Traditionally, hyperbaric oxygen therapy has been employed after failure to respond to other treatments. However, a recent meta-analysis of hyperbaric oxygen use in managing 190 patients with HC reported that 76.3 % of patients had improvement or resolution of hematuria [66]. Corman and associates reported on 57 patients treated with HBO_2 between 1988 and 2001 at our institution, and 86 % of patients had complete resolution or marked reduction in hematuria episodes [67]. Despite these encouraging results from high volume institutions, reports from other centers have suggested lower response rates [68, 69].

Although hyperbaric oxygen has traditionally been used to treat HC secondary to radiotherapy, recent case reports suggest that it also may have a role in the treatment of cyclophosphamide-induced HC that is refractory to first-line management [70].

We strongly recommend hyperbaric oxygen as an early intervention to manage nonlife-threatening HC.

Intravesical Therapies

Most second-line therapies are intravesical instillations with variable efficacy and side effect profiles. They generally cause mucosal fibrosis and scarring as a form of chemical coagulation.

Alum

Intravesical 1 % alum solution (10 g aluminum potassium sulfate in 1 L of distilled water) has been used with reasonable efficacy and minimal side effects [71]. Alum functions as a chemical astringent causing protein precipitation over bleeding surfaces. It is of paramount importance to evacuate all clots from the bladder before administering Alum to prevent the development of giant bladder clots. It is usually well tolerated by continuous bladder instillation up to 300 cc/h and may take several days to induce hemostasis. It can be administered to patients with no risk of bladder scarring and can be used in patients with reflux [72]. Potential side effects include suprapubic pain, aluminum toxicity, and renal dysfunction. Moreover, toxicity can occur even in patients with normal kidney function [73]. Isolated reports of treating alum toxicity include using intravenous feroxamine [74].

Formalin

Intravesical 1 % formalin (with 0.37 % formaldehyde gas in solution) induces bladder mucosal fibrosis. While bedside instillation of formalin can be performed at dilute concentrations (<0.1 %) in critically ill patients, typical formalin therapy is performed cystoscopically under general or regional anesthesia. Prior to instillation a cystogram must be performed in order to rule out the presence of

vesicoureteral reflux. If reflux is noted, embolization catheters should be placed in the affected ureter to prevent formalin reflux into the upper tracts.

One percent formalin is instilled for 30 min before the bladder is reinspected cystoscopically. If bleeding persists, repeat instillation of up to 4 % formalin may be performed (30 min intravesical dwell time per increased concentration) in order to effect cessation of bleeding. While mucosal fibrosis is typically observed histologically and is associated with resolution of the hematuria, bladder fibrosis and contracture are commonly seen following longer formalin dwell times and higher therapy concentrations. Such fibrosis and associated edema may result in profound bladder symptoms, pain, and dysfunction [75].

Miscellaneous Intravesical and Oral Treatment Options

Other intravesical options include ε-aminocaproic acid. This agent acts by inhibiting formation of stable plasmin. Fibrin degradation cannot occur effectively, and stable blood clots are formed to stop further bleeding. Short-term results appear favorable [76], but widespread use is limited due to its acceleration of clot formation, which can cause renal unit loss with bleeding from an upper tract source [77].

Intravesical prostaglandins E_1, E_2, and $F_{2\alpha}$ (Carboprost®) have been tried with varying success [78–80]. Silver nitrate is another intravesical option, but reports of intraureteral salt precipitation and subsequent urinary obstruction temper its widespread use [81].

Cidofovir is a cytidine nucleoside analog that has activity against polyomavirus and adenovirus [82] and has been used intravesically in a small group of patients with BK adenovirus-associated HC with reported success [83]. Its clinical utility awaits testing in a formal clinical trial setting.

Pentosanpolysulphate (PPS) is a synthetic glycosaminoglycan molecule that is used in patients with interstitial cystitis [84] and is thought to replace damaged bladder wall mucosa and prevent absorption of noxious chemicals in these patients. Small case series in adult patients with HC have demonstrated success with its use [85, 86]. Its theoretical disadvantages include very low intravesical drug concentration (1–3 %) requiring a number of weeks of treatment before clinical response is achieved and an unknown toxicity profile in pediatric patients.

Emergency Options

Temporary Urinary Diversion

When uncontrolled bleeding is apparent, temporary urinary diversion may be performed to reduce distress from clot retention. Moreover, urokinase, which is present in urine is a potent thrombolytic that activates plasminogen and prevents hemostasis. Thus, urinary diversion helps promote hemostasis at the metabolic level in addition to its mechanical function. Suprapubic cystostomy or bilateral percutaneous nephrostomy tube placement [1] can slow bleeding while more invasive surgery is contemplated.

Specifically in the pediatric population, the small size of the urethra can limit catheter size (10–14 Fr), and thus impede the effective evacuation of large clots. In this instance, suprapubic cystostomy can be performed to aid in clot evacuation and associated pain, particularly in palliative pediatric cancer patients with intractable bleeding [87].

Embolization or Surgical Ligation of Internal Iliac Vessels

Selective transfemoral hypogastric artery embolization has been used to treat intractable hematuria due to tumor and trauma [88]. Similarly, embolization has been reported in patients with refractory HC after stem cell transplant, demonstrating full resolution in 8 of 10 patients [89].

Open Vesicostomy/Subtotal or Total Cystectomy

Exploratory laparotomy is the most aggressive and last resort. Attempts at ligating internal iliac arteries may stop the hemorrhage, and open vesicostomy may control bleeding.

In uncontrolled bleeding, subtotal cystectomy with two-layer repair using absorbable sutures may be adequate for single or clusters of persistent bleeding spots in proximity. However, this treatment is not appropriate therapy for trigonal bleeding, for which total cystectomy [90] is usually indicated.

Potential Future Therapies

Antiviral Therapies

Intravenous ribavirin [91] is an antiviral agent that can suppress infections of adenovirus subtypes 11 and 35, thereby reducing infections in individuals immunocompromised from bone marrow or renal transplantations. Another option is intravenous or intramuscular vidarabine [92].

Miscellaneous

Other reported treatment options include use of oral conjugated estrogens [93], intravenous factor XIII concentrate [94], recombinant activated factor VII [95], and intravesical recombinant human granulocyte-macrophage colony-stimulating factor [96].

Summary

Moderate to severe hemorrhagic cystitis (HC) has been reported in up to 5 % of patients following radiotherapy for prostate cancer and may occur up to 10 years following treatment. HC is caused by chronic fibrosis and progressive endarteritis of the bladder mucosa. The diagnosis is based upon clinical presentation, histologic assessment, and the absence of other sources of bleeding (e.g., malignancy).

The primary treatment modality for HC is bladder irrigation. Oral and intravenous agents such as aminocaproic acid, estrogens, and sodium pentosan polysulfate have been used with limited success. Intravesical treatments with alum, silver nitrate, and formalin are employed if bleeding is recalcitrant. Finally, selective embolization of the hypogastric arteries, urinary diversion, and cystectomy may be used in severe cases. In recent years, HBO_2 has emerged as a primary option in the management of this challenging condition.

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Priapism

15

Kevin O'Brien, Martin Gross, and Ricardo Munarriz

Introduction

The term priapism is derived from the Greek god Priapus, the god of seduction, fertility, and sexual love, who was also known for his giant phallus [1]. Since the first reported case of priapism in 1824 by Callaway [2], limited attention has been placed on the study of the incidence, etiology, pathophysiology, diagnosis, and timely treatment of priapism. As a result priapism is associated with less than ideal patient outcomes including permanent and irreversible erectile dysfunction, and the concomitant devastating psychosocial consequences.

Frank Hinman Sr. first described the natural history of priapism in 1914 [3]. His son, Frank Hinman Jr., suggested in 1960 that ischemia, increased blood viscosity, and congestion were responsible for the pathophysiology of priapism [4]. Dr. Hinman also reported transient attacks of priapism [3], but the term "stuttering priapism," also known as recurrent priapism, is attributed to Emond (1980) who reported intermittent repeated episodes in patients with sickle cell disease [5]. The first case of arterial or non-ischemic priapism was reported in 1960 by Burt et al. [6]. It was not until 1983 that Hauri reported radiological differences between arterial and ischemic priapism [7].

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The purpose of this chapter is to clarify the epidemiology, definitions, etiology, pathophysiology, and management of ischemic and arterial priapism so that the urologist/andrologist feels comfortable discussing and treating this rare but devastating condition.

Epidemiology

Well-designed, community-based epidemiologic studies investigating the prevalence and incidence of priapism are limited. Current data reveal that the incidence of priapism in the general population is low. A Finnish study from 1995, based on hospital discharge data, established the incidence of priapism between 0.3 and 0.5 cases per 100,000 person–years with a peak incidence of 1.1 cases per 100,000 person–years in the final years of the study. This increase was attributed to the new use of intracavernosal vasoactive agents introduced for the treatment of erectile dysfunction [8].

More recently, Eland et al. conducted a population-based retrospective cohort study using the Integrated Primary Care Information database, a longitudinal computer-based record of all patients seen by general practitioners in the Netherlands. This study demonstrated a slightly higher incidence of non-iatrogenic priapism (0.9 cases per 100,000 person–years) and a similar incidence of iatrogenic priapism [9].

The incidence of priapism in the United States, Latin American, and African countries may be

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higher due to a greater incidence of hemoglobinopathies, such as sickle cell disease. A questionnaire-based study in five centers in the UK and Nigeria of 130 patients with sickle cell anemia reported that the prevalence of priapism among patients with sickle cell anemia was 35 % [10]. The risk of priapism in sickle cell patients has elsewhere been reported to range from 29 to 42 % [5]. The vast majority of priapism is ischemic in nature (95 %) and 79 % of these cases continue to be idiopathic despite advances in the field. More interestingly, 21 % of cases are associated with alcohol or drugs [11].

Definitions

The American Urological Association (AUA) published in 2003 the following definition and classification for priapism: a persistent erection that continues for hours or that is unrelated to sexual stimulation [12]. The panelists also set a minimum duration of 4 h and reported that priapism is an emergency which requires urgent management. *Ischemic priapism* (veno-occlusive, low flow) is a persistent erection without sexual stimulation characterized by little to no blood flow and abnormal cavernous blood gases (hypoxia, hypercapnia, and acidosis). In contrast, *non-ischemic priapism* (arterial, high flow) is a persistent erection without sexual stimulation caused by unregulated cavernous inflow. *Recurrent priapism* (stuttering) is a variant of ischemic priapism in which painful erections occur repeatedly with intervening periods of detumescence.

Etiology of Ischemic Priapism (Veno-Occlusive)

Drugs, Toxins, Hormones, and Parenteral Hyperalimentation

Prescription and recreational drugs are responsible for up to 80 % of cases of ischemic priapism (Table 15.1) [13]. Intracavernosal injection of vasoactive drugs for the management of erectile dysfunction has become the most common cause of drug-induced priapism [14]. Very rarely, PDE 5 inhibitors have been linked to cases of ischemic priapism [15–18].

Table 15.1 Etiology of priapism

Ischemic priapism (veno-occlusive or low flow)
Medicines and drugs
Intracavernosal agents: papaverine, prostaglandin E1, phenoxybenzamine
Medicines acting on the central nervous system: trazadone, benzodiazepines, phenothiazines
Anti-hypertensives: prazosin, phenoxybenzamine, calcium and beta blockers, hydralazine
Anticoagulants: heparin, warfarin
Hormones: testosterone, gonadotropin-releasing hormone, antiestrogens (tamoxifen)
Illicit drugs: cocaine and marijuana
Parental nutrition
Others: carbon monoxide, alcohol, spider and scorpion venom
Infectious diseases: malaria, rabies, syphilis, mumps
Hematologic diseases
Hyperviscous states: polycythemia vera
Hemoglobinopathies: sickle cell, thalassemia
Immunologic diseases: Lupus, protein C deficiencies
Metabolic diseases: gout, diabetes, nephrotic syndrome, renal failure, amyloidosis, Fabry's disease, hypertriglyceridemia
Neurologic diseases: spinal cord injuries, autonomic neuropathy, spinal stenosis
Neoplastic disorders: leukemia, multiple myeloma, infiltration of prostate or urethral cancer, metastasis
Idiopathic
Non-ischemic or arterial priapism
Penetrating perineal trauma
Nonpenetrating perineal trauma
Idiopathic

Certain antihypertensive drugs can induce priapism through alpha-adrenergic antagonism, by preventing or delaying physiologic detumescence, or by direct relaxation of cavernous smooth muscle [19].

Duggan and Morgan first reported the association between heparin and priapism after four patients developed ischemic priapism while on heparin for the management of myocardial infarction [20]. This association was further studied by Singhal et al. in which 17 of 3,337 hemodialysis patients who received heparin experienced an

episode of priapism during or shortly after hemodialysis [21]. Although the mechanism by which heparin induces priapism is unclear, it is hypothesized that a relatively hypercoagulable state may develop after heparin therapy is discontinued [22]. In addition, hemodialysis patients may have a defect of von Willebrand's factor, a platelet adhesion molecule that perpetuates a hypercoagulable state that might increase the risk of ischemic priapism [23]. Interestingly, other anticoagulants such as warfarin have also been associated with this condition.

Psychotropic drugs can cause priapism. Tricyclic antidepressants have rarely been associated with priapism, and trazodone, an atypical antidepressant and hypnotic, has commonly been associated with prolonged erections and priapism [24, 25]. The most likely mechanism is α-adrenergic blockade, which interferes with the normal detumescence mechanism [26, 27]. Antipsychotic drugs such as phenothiazines have also been associated with ischemic priapism. The mechanism by which these antipsychotic drugs cause priapism is not fully understood but is believed to be due to blockade of dopamine D1 receptors and to a lesser degree by their alpha blocking, antihistamine, anticholinergic, and antiserotonergic properties [28, 29].

Cocaine, either by intranasal or topical [30, 31] administration, has become a common cause of ischemic priapism. The pathophysiologic mechanism is complex and multifactorial. On one hand, cocaine is a potent norepinephrine reuptake inhibitor, which may deplete neuronal norepinephrine stores and prevent detumescence [32]. On the other hand, cocaine is a potent serotonin reuptake inhibitor, which may cause central nervous system stimulation and peripheral vasodilation [33, 34]. Marijuana has also been associated with priapism [35].

In the past, when parenteral hyperalimentation contained high fat emulsions, ischemic priapism was frequently reported. Several pathophysiologic mechanisms such as hypercoagulability, fat embolism, capillary thrombosis, and decreased capillary blood flow have been hypothesized to be responsible for the development of parenteral hyperalimentation-induced ischemic priapism [36–38].

Finally, toxins (black widow spider venom) [35, 39], parasitic infections (malaria) [35], various hormones such as testosterone [40–42] or antiestrogens (tamoxifen) [43], and nutritional supplements containing ephedrine [32] have been associated with ischemic priapism.

Hematologic Disorders

Hematologic disorders, in particular hemoglobinopathies, are the most common cause of priapism in the pediatric population [44, 45]. The incidence of sickle cell disease in African Americans is estimated to be 8.2 %, and between 10 and 89 % of patients with sickle cell disease will experience priapism [46–48]. The vast majority of sickle cell priapism events are initiated during nocturnal erections. It is probable that the combination of erythrocyte functional and structural abnormalities, low oxygen tension, and decreased corporal pH during prolonged nocturnal erections may induce the formation of irreversible sickled erythrocytes which prevent venous outflow and normal penile detumescence. Sickle cell disease is the most common cause of stuttering priapism, a rare and poorly described syndrome characterized by multiple or recurrent episodes of ischemic priapism.

Other hemoglobinopathies (thalassemia) [49] and hyperviscosity states such as leukemia and polycythemia have also been associated with priapism [50, 51]. The pathophysiology is probably similar to that of sickle cell anemia [50, 51].

Metabolic, Neurologic, and Malignant Disorders

Metabolic disorders such as nephrotic syndrome, gout, amyloidosis and Fabry disease are rare causes of priapism and medical references are limited to a few case reports [35, 51]. The most likely pathophysiologic mechanism is due to the obstruction of venous outflow.

Spinal cord trauma, spinal cord compression, autonomic neuropathy, stroke, and brain tumors are rare causes of priapism [35, 52, 53] and

generally resolve spontaneously or require minimal intervention.

Malignant priapism is a rare condition [54–56]. Nevertheless, the most common primary tumors responsible for this presentation are bladder, prostate, rectosigmoid colon, and kidney (30 %, 30 %, 16 %, and 11 %, respectively) [57]. The pathophysiological mechanism by which malignant tumors may lead to priapism is probably obstruction of venous drainage or partial replacement of the sinusoids, which might promote stasis and thrombosis.

Idiopathic

The etiology of ischemic priapism is unknown in approximately 30–50 % of cases [11]. A detailed and thorough assessment is needed to exclude known causes of priapism, including those associated with significant complications and morbidities such as sickle cell disease.

Pathophysiology of Ischemic and Arterial Priapism

Ischemic priapism results from an imbalance of the vasoconstrictive and vasorelaxatory mechanisms leading to a penile compartment syndrome which is biochemically characterized by hypoxia, hypercapnia, and acidosis. Prolonged corporal smooth muscle exposure to these conditions causes irreversible damage to erectile tissue due to necrosis and subsequent corporal fibrosis.

Hypoxemia activates endothelial cells, leading to a cascade of reactions characterized by increased neutrophil adhesion, decreased mitochondrial respiratory chain activity, and an increase in intracellular calcium.

Reestablishing corporal blood flow during the management of ischemic priapism results in reperfusion of ischemic tissues. This drastic increase in corporal oxygen tension generates reactive oxygen species that may cause further tissue damage. Based on the cardiac reperfusion model described by Goldhaber and Weiss [58], we have suggested that several damaging events take place during penile ischemia and reperfusion in the management of priapism:

1. Endogenous scavengers of oxygen-free radicals decrease during ischemia resulting in reduced levels of antioxidant effect
2. Decreased mitochondria aerobic metabolism results in the production of reactive oxygen species (ROS)
3. Increased ATP hydrolysis results in the accumulation of hypoxanthine, which is subsequently converted to uric acid, another source of ROS
4. The NO pathway generates peroxynitrite, peroxynitrite anion, and hydroxyl radical (free radicals)
5. Lipid peroxidation and infiltration of the vasculature with neutrophils produces several oxygen-free radicals (including hydrogen peroxide, hydroxyl radicals, and hypochlorous anions) that are released in response to ischemia/reperfusion [59].

Arterial or non-ischemic priapism results from unregulated cavernous arterial flow as a result of acute penile or perineal trauma, which leads to the formation of an arterial-lacunar fistula [60, 61]. Turbulent arterial flow into the fistula causes unregulated release of endothelial nitric oxide, a potent vasodilator and anticoagulant that prevents penile detumescence and clotting of the arterial-lacunar fistula.

Recommendations from the American Urological Association [12]

1. *Determine whether the priapism is ischemic or not before starting treatment [12].*

   The diagnosis of priapism is a clinical diagnosis confirmed by an assessment of blood flow status of the corpora cavernosa. This is determined by aspiration of corporal blood and/or penile duplex Doppler ultrasound (Fig. 15.1). The clinical differences and arterial blood gases of ischemic and non-ischemic priapism are summarized in Tables 15.2 and 15.3. Additionally, general diagnostic tests (blood count, platelets, differential, reticulocyte count, hemoglobin electrophoresis, urinalysis, PSA, and cocaine metabolites in urine

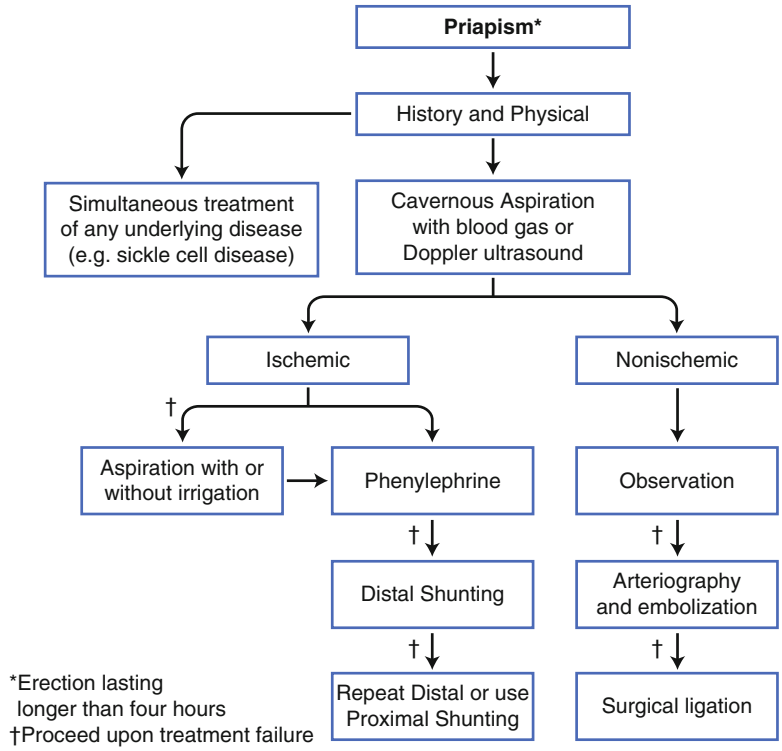

Fig. 15.1 Management algorithm for priapism. (Adapted from Montague et al. [12])

Table 15.2 Clinical findings in priapism

	Ischemic priapism	Non-ischemic priapism
Fully rigid cavernosa	Usually	Rarely
Penile pain	Usually	Rarely
Abnormal penile blood gas	Usually	Rarely
Hematologic abnormalities	Usually	Rarely
Recent intracavernous injections	Common	Sometimes
Perineal trauma	Rarely	Common

Source: Adapted from Montague et al. [12]

Table 15.3 Blood gas findings

	PO_2 (mmHg)	PCO_2 (mmHg)	pH
Normal arterial blood	>90	<40	7.4
Mixed venous blood	40	50	7.35
Ischemic priapism	<30	>60	<7.25

Source: Adapted from Montague et al. [12]

or serum) should be considered in the search for etiologic factors

2. *The treatment of patients with priapism requires simultaneous management of the disease responsible for the priapism (sickle cell disease, malignancies, etc.) as well as immediate intracavernous management [12].*
3. *The treatment of patients with priapism must proceed in a phased manner to achieve resolution of priapism as soon as possible. Initial*

Table 15.4 Adrenergic agents use in the treatment of ischemic priapism

	Alpha	Beta 1	Beta 2
Ephedrine	+	++	++
Epinephrine	+++	+++	+++
Norepinephrine	+++	++	++
Phenylephrine	+++	Minimal or none	Minimal or none

treatment may consist of an aspiration irrigation therapy with or without cavernous or intracavernous administration of sympathomimetic agents [12].

We also recommend a penile block or local anesthetic with or without systemic analgesia to minimize the suffering of the patient and maximize the effectiveness of invasive procedures, as these tend to be painful.

4. *If aspiration/irrigation was not effective, it is recommended to repeat the administration of sympathomimetic agents prior to surgery [12].*
5. *The use of phenylephrine is recommended due to its fewer cardiovascular effects (Table 15.4) [12].*

   Another reason to use phenylephrine over other sympathomimetic agents is their alpha-1 agonist activity and low beta-1 activity [62].
6. *The administration of 100–500 μg/mL every 3–5 min for a period of 1 h is recommended before deciding that the treatment was not effective. In children or patients with severe cardiovascular disease lower dosages are recommended [12].*

   We demonstrated that it is necessary to use higher doses of phenylephrine (1,000 μg/mL every 10 min) than those recommended by AUA to overcome the reduced affinity of alpha-adrenergic receptors induced by penile acidosis during ischemic priapism [63].
7. *During the administration of sympathomimetic agents, physicians should be alert to symptoms and signs associated with adverse systemic effects such as hypertensive crisis, headache, reflex bradycardia, and palpitations. It is also recommended to monitor patients with significant cardiovascular risk factors with an electrocardiogram and blood pressure measurements [12].*
8. *Surgical management of ischemic priapism should be considered only after nonsurgical treatment has failed (aspiration/irrigation, administration of sympathomimetic agents) [12].*
9. *A distal or cavernoglanular shunt should be the treatment of choice because it is easier to perform and has fewer complications (Figs. 15.2 and 15.3). Proximal shunts (Quackel's or Grayhack) are indicated in cases where the distal shunt was not effective (Fig. 15.4) [12].*

The resolution of priapism should be determined by physical examination of the penis, and in cases of partial resolution, it is mandatory to carry out studies of the corporal flow state by corporal aspirate or duplex Doppler ultrasound. If the episode of priapism has resolved satisfactorily, the patient may be given a medical discharge with detailed instructions and close monitoring. In the case of partial resolution (partial penile detumescence with cavernosal blood flow present), we recommend admission with regular physical examination and repeated evaluation of penile blood flow. Adrenergic agonists can be administered (intracavernosal and/or orally) to induce complete detumescence. If first-line interventions are repeated for several hours without resolution of ischemic priapism, the establishment of surgical shunts is suggested.

In the vast majority of cases distal shunts are effective, particularly the T-shunt (percutaneous) and the Al-Ghorab (open). In the T-shunt a penile block is performed, and then a number 10 scalpel blade is placed vertically through the glans approximately a half-centimeter superior and lateral to the meatus. The blade pierces the corpus cavernosum via the glans and is then rotated 90° away from the urethra and removed. The blood is then milked out of the wound and the procedure is repeated on the other corpus cavernosum if erection returns or persists. Because it can be performed under local anesthesia, the T-shunt has the advantage of avoiding the operating room. In severe cases, however, where priapism has persisted for longer than 36 h, bilateral T shunts with passage of 20-Fr

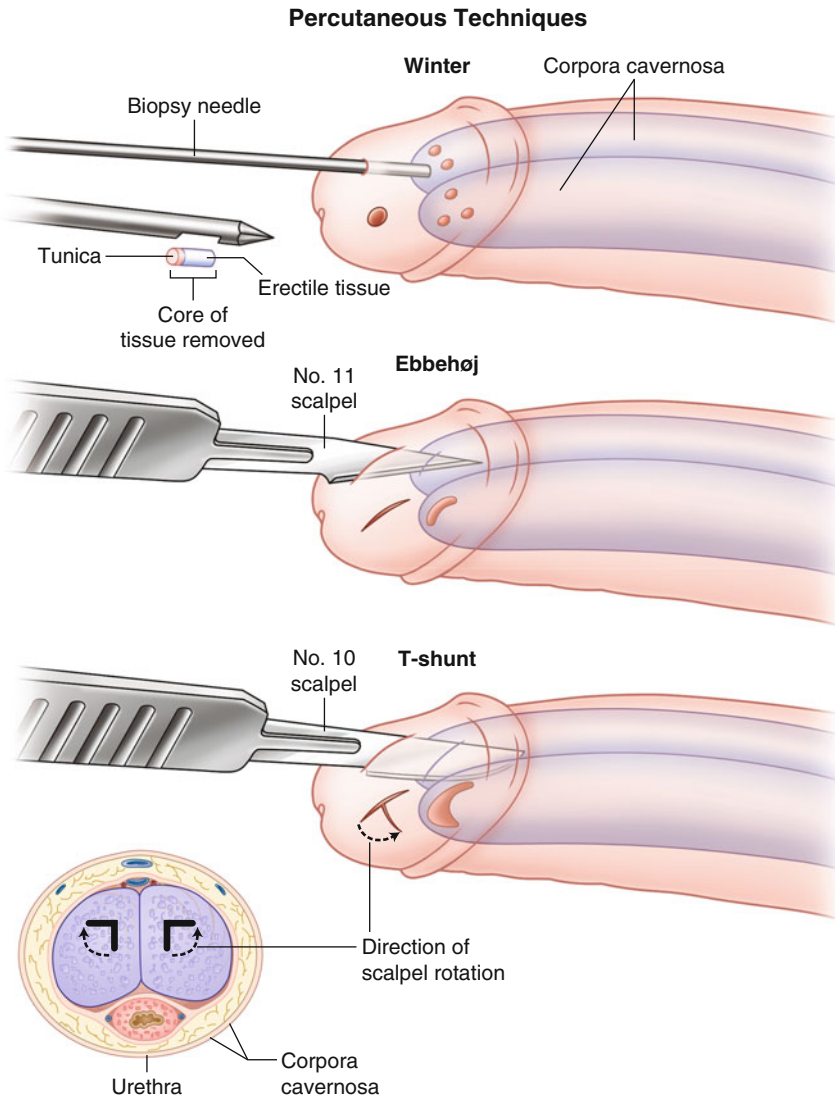

Fig. 15.2 Percutaneous shunts. (With permission of Wiley-Blackwell. J Sex Med. 2006; 3:749–752.)

dilators down to the crus are recommended, which requires general anesthesia [64].

In the Al-Ghorab shunt, the patient is placed under general anesthesia and a 2-cm transverse incision is made on the glans at the level of the tips of the corpora. Dissection is carried down to the corporal tips, which are grasped with 2-0 Vicryl stay sutures. A wedge of tunical tissue is excised from each corporal tip and deoxygenated blood is milked out. In the "Corporal Snake" variant introduced by Burnett, the tips are instead incised and a Hegar dilator is advanced proximally several centimeters through each of the tunical incisions [65]. After evacuation of corporal blood via manual compression and release, the glans skin is then approximated with 4-0 chromic sutures. The Al-Ghorab shunt has the advantage of highly effective resolution of ischemic priapism in a controlled operating room setting [66, 67].

10. *Oral treatments are not indicated for the emergent treatment of ischemic priapism [12].*
11. *In the management of arterial or non-ischemic priapism, the aspiration of the corpora cavernosa has only diagnostic value. Aspiration*

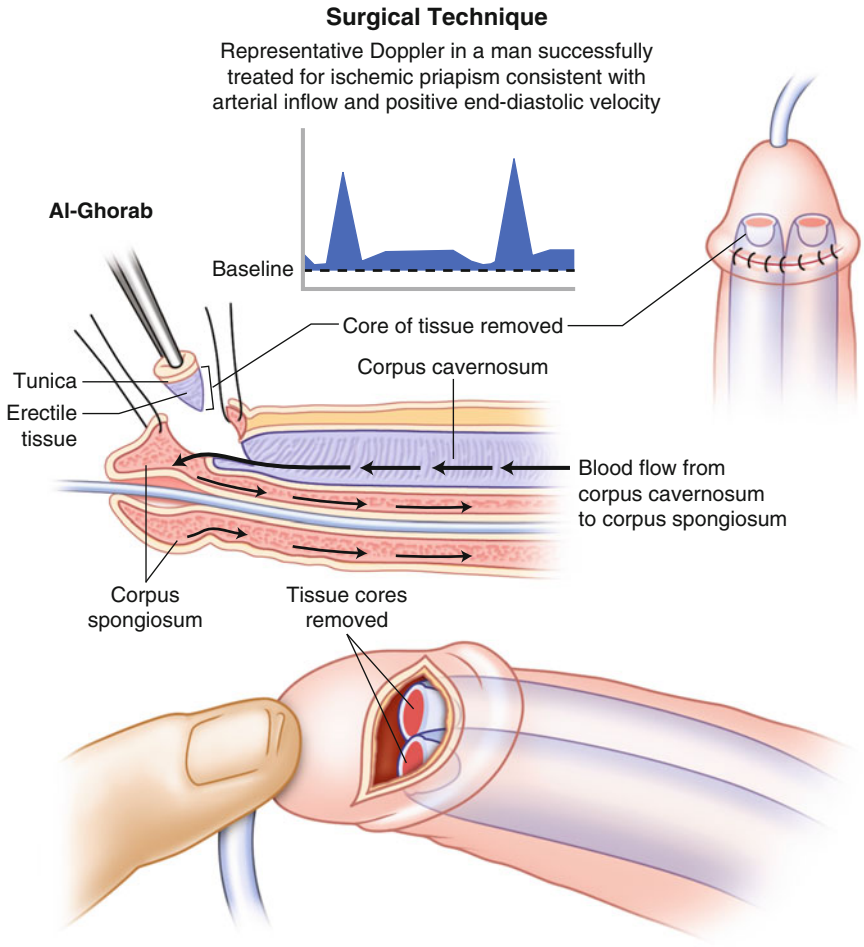

Fig. 15.3 Al-Ghorab shunt. (With permission of Wiley-Blackwell. J Sex Med. 2006; 3:749–752.)

with or without injection of sympathomimetic agents is not recommended [12].

The diagnosis of high flow priapism is usually made by history (perineal trauma is most often reported by patients) and physical examination (partial non-painful erections). Duplex Doppler ultrasound is a noninvasive method that allows viewing and simple determination of the arterial-lacunar fistula (Fig. 15.5). This form of priapism is not a compartment syndrome, so there is no medical emergency.

12. *Initial management of arterial priapism should be observation, but in selected cases and after an extensive discussion (risks, benefits), more invasive treatments can be considered [12].*

Androgen blockade has recently been shown to be effective in the treatment of non-ischemic priapism. It is believed that by limiting nocturnal penile blood flow and erections, androgen blockade may cause spontaneous closure of the cavernous artery fistulae [68].

13. *Embolization is recommended in patients with arterial priapism seeking treatment. The use of absorbable material (clot, gel/foam) is preferred over nonabsorbable or permanent materials [12].*
14. *Surgical management of arterial priapism (ligation of the fistula) should be a last resort and requires the use of intra-operative ultrasonography [12].*
15. *The aim of the management of patients with recurrent priapism is the prevention of future episodes, while the management of*

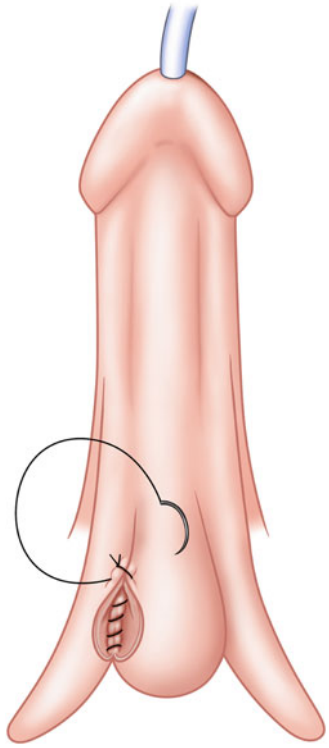

Fig. 15.4 Proximal shunts. (With permission of Wiley-Blackwell. J Sex Med. 2010;7:476–500.)

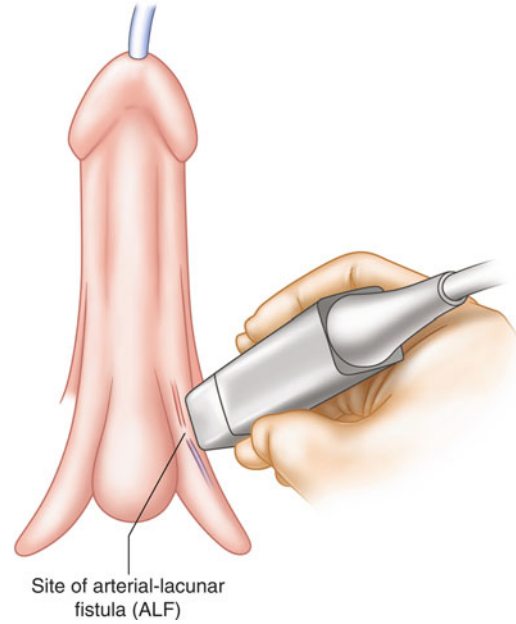

Fig. 15.5 Duplex Doppler ultrasonography of the proximal corpora for viewing and simple determination of the arterial-lucunar fistula. (With permission of Wiley-Blackwell. J Sex Med. 2010;7:476–500.)

each episode should follow the recommendations for the management of ischemic priapism [12].

16. *Anti-androgens or agonists of gonadotropin-releasing hormones can be used in patients with recurrent priapism as long as the patient has achieved sexual and physical maturity [12].*
17. *The use of self-administered intracavernosal phenylephrine should be considered in patients not responding to or rejecting the systemic treatment of recurrent ischemic priapism [12].*

Erectile Function and Duration of Ischemic Priapism

The most important predictor of the maintenance of premorbid erectile function is the duration of priapism, making rapid intervention essential. Kulmala et al. reported that men with less than 24 h of priapism have 92 % chance of returning to premorbid erectile function, compared with 22 % if the event is spread over a period longer than 7 days [69]. More recently, Bennett et al. reported that 100 % of patients with priapism of a 12 h duration noted a decrease in penile rigidity and no patient with priapism of 36 h or more maintained his erectile function. However, between 44 and 78 % of patients with priapism of 12–36 h were able to generate functional erections with or without the use of sildenafil [70].

Management of Recurrent (Stuttering) Priapism

Pathophysiology: Research indicates that deregulation of the signaling system of nitric oxide may be partly responsible for prolonged erections and recurrent priapism in patients suffering from hemoglobinopathies such as sickle cell disease. Lin and colleagues demonstrated that phosphodiesterase is negatively regulated by penile ischemia [71]. Subsequently, Champion and colleagues reported a decrease in the expression and activity of phosphodiesterase type 5 in animal models lacking endothelial nitric oxide synthase (eNOS) and sickle cell transgenic mice [72]. More important was the res-

Table 15.5 Pharmacological prevention of recurrent priapism

Medication	Administration	Dosage	Cost (dollars)	Side effects
Anti-androgens	Oral		230–440	Gynecomastia, peripheral edema, anemia, hepatotoxicity, vasomotor effects
Bicalutamide		50 mg/day	115	
Flutamide		125–250 mg 3 times/day		
GNRH	Intramuscular	7.5 mg/month	625	Gynecomastia, vasomotor effects, fatigue, osteoporosis, depression, etc.
Leuprolide				
Baclofen	Oral	20–40 mg/day	30–40	Sedation, dizziness, fatigue, confusion, visual problems
Digoxin	Oral	0.5 mg/day	14	Cardiac effects, gastrointestinal, gynecomastia, dizziness, visual problems
Phenylephrine	Intracavernosal	100–150 mg every 5 min	8–10/vial	Hypertension, bradycardia, headaches, palpitations
Gabapentin	Oral	300 mg 3 times/day	125	Leukopenia, dizziness, fatigue, ataxia, weight gain, vision problems
Ketoconazole	Oral	200 mg 2 times/day	110	Hepatotoxicity, gastrointestinal weakness
Ketoconazole + prednisolone	Oral	200 mg 3 times/day 5 mg/day	170 850	

Source: Adapted from Levine et al. [73]

toration of normal levels of phosphodiesterase type 5 with a resolution of priapism episodes through normalization of eNOS activity by genetic methods. These findings provide a molecular explanation of the pathophysiology of recurrent ischemic priapism in patients with sickle cell disease

Pharmacotherapy: A multitude of pharmacological agents have been used in the management of recurrent priapism with inconsistent results that are often limited by side effects (Table 15.5) [73]. As in some cases, the AUA Guidelines recommend the use of intracavernosal self-administered phenylephrine [12].

Treatment with Inhibitors of Phosphodiesterase Type 5

Burnett and colleagues reported that six of seven patients with recurrent priapism that was either idiopathic or secondary to sickle cell disease responded favorably to treatment with inhibitors of phosphodiesterase type 5 [74]. Interestingly, Tzortzis and colleagues reported the case of a patient with thalassemia complicated by recurrent priapism who responded favorably to the use of inhibitors of phosphodiesterase type 5 [75]. However, anecdotal experience of many experts in sexual medicine is not consistent with the results reported by Burnett and Tzortzis. A well-designed prospective study is needed to assess the effectiveness of inhibitors of phosphodiesterase type 5 in patients with recurrent priapism.

Summary

Ischemic priapism is a pathological penile erection that persists beyond, or is unrelated to, sexual stimulation and requires immediate assessment and urgent medical and/or surgical treatment to prevent irreversible corporal fibrosis and permanent erectile dysfunction. Non-ischemic priapism, a less common condition, is usually caused by perineal trauma resulting in arterio-lacunar fistula characterized by a deregulation of cavernous flow. As it is not a compartment syndrome, arterial priapism is not a medical emergency. It does, however, require a medical evaluation and in some cases elective treatment.

Recurrent priapism is a variant of ischemic priapism in which painful erections are repeated with periods of flaccidity. The pathophysiology is not fully established but is believed to be due to a deregulation of nitric oxide signaling. Recently, several researchers have used phosphodiesterase inhibitors in the management of recurrent priapism secondary to hemoglobinopathies. Further studies are needed to gauge the reproducibility of these results.

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The Acute Scrotum

16

Chad M. Gridley and Hiep T. Nguyen

Introduction

Any male child, adolescent, or adult who presents with complaints of scrotal pain, tenderness, or swelling should be promptly evaluated. Although the differential diagnosis is extensive, testicular torsion and rupture should be considered based on a thorough history, physical examination, and appropriate radiological evaluation. Testicular salvage is only possible when the diagnosis is considered early in the evaluation of the patient with the acute scrotum. Timely and accurate diagnosis is required to prevent testicular loss. This chapter reviews testicular torsion and other causes of the acute scrotum in children, the latter disorders also being covered in detail for adult patients in Chapters 7 and 9.

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Testicular and Appendiceal Torsion

Torsion of the spermatic cord and testicular/epididymal appendages is one of the common causes of an acute scrotum. Torsion of the former is a true surgical emergency; that of the latter requires no surgical intervention. Although testicular torsion can occur at any age, there is a bimodal distribution in the age of presentation, during the neonatal period and during puberty. Extravaginal torsion is caused by the spermatic cord twisting on itself above the level of the tunica vaginalis and is seen in the neonatal period (Fig. 16.1). Several explanations, including multiparity, excessive uterine pressure, and a strong cremasteric contraction, have been suggested [1].

Intravaginal torsion involves torsion of the spermatic cord within the tunica vaginalis. This so-called bell clapper deformity (Fig. 16.2) is associated with an abnormal fixation of the testis and epididymis and is most commonly seen in adolescents who present with torsion. However, testicular torsion is not limited to children and may occur in young adults and the middle aged. Patients with the bell clapper deformity may also present with intermittent torsion, in which the cord can twist on itself and then spontaneously untwist (Fig. 16.3).

The appendix testis (Fig. 16.4a), a Müllerian remnant, and the appendix epididymis (Fig. 16.4b), a Wolffian remnant, are also susceptible to torsion. Torsion of these appendages occurs more commonly during adolescence. It has been sug-

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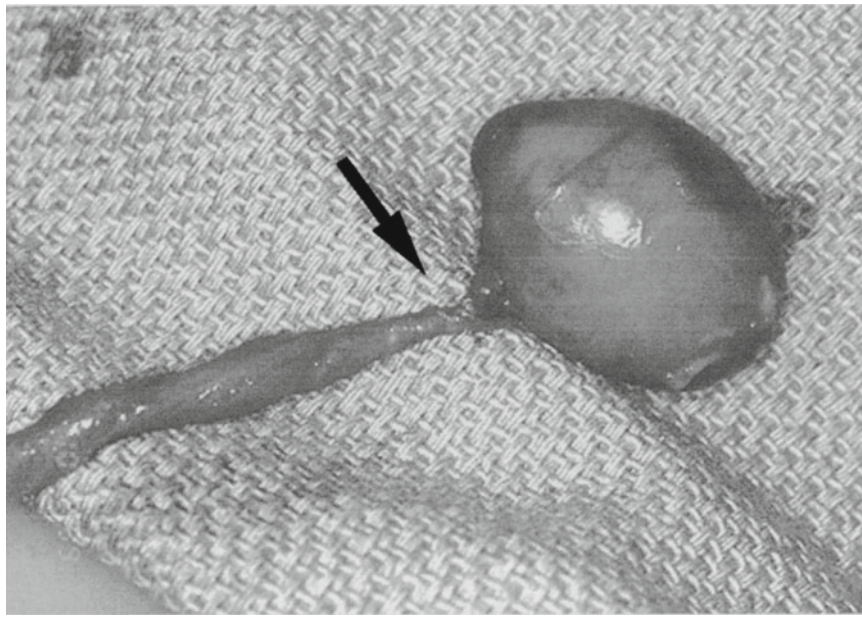

Fig. 16.1 The left testis of a 3-day-old infant with an extravaginal torsion. Note that the entire cord has twisted above the tunica vaginalis (*arrow*). The epididymis and testis are enclosed within the tunica; consequently, they are not visualized

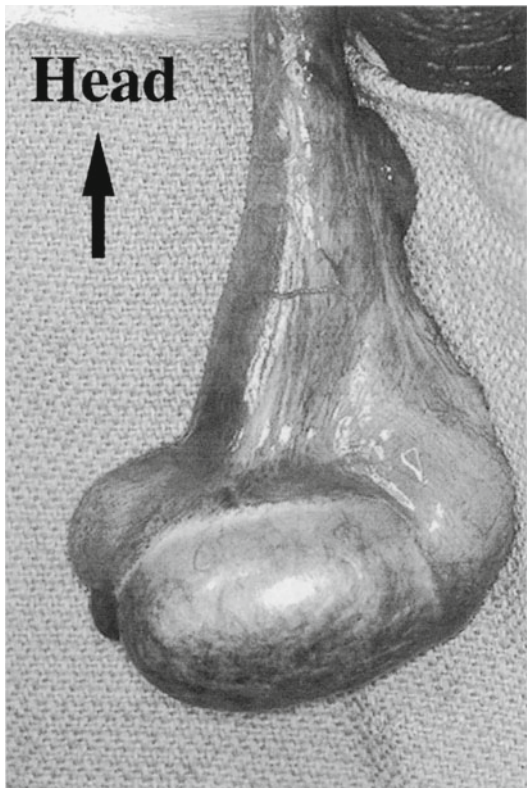

Fig. 16.2 The right testis of a 14-year-old boy who presents with intravaginal torsion has the bell clapper deformity, which may predispose to torsion of the spermatic cord

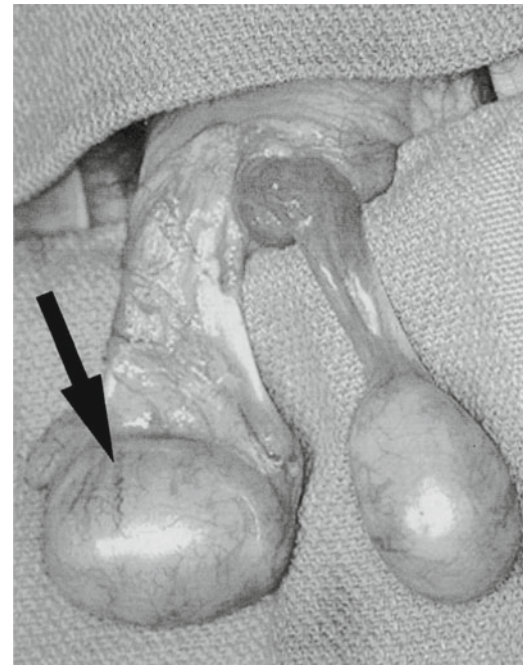

Fig. 16.3 This patient presented with five previous episodes of acute right testicular pain that spontaneously resolved after 10–15 min. On scrotal exploration, a bell clapper deformity was noted on the right side. Note the normal lie of the left testis

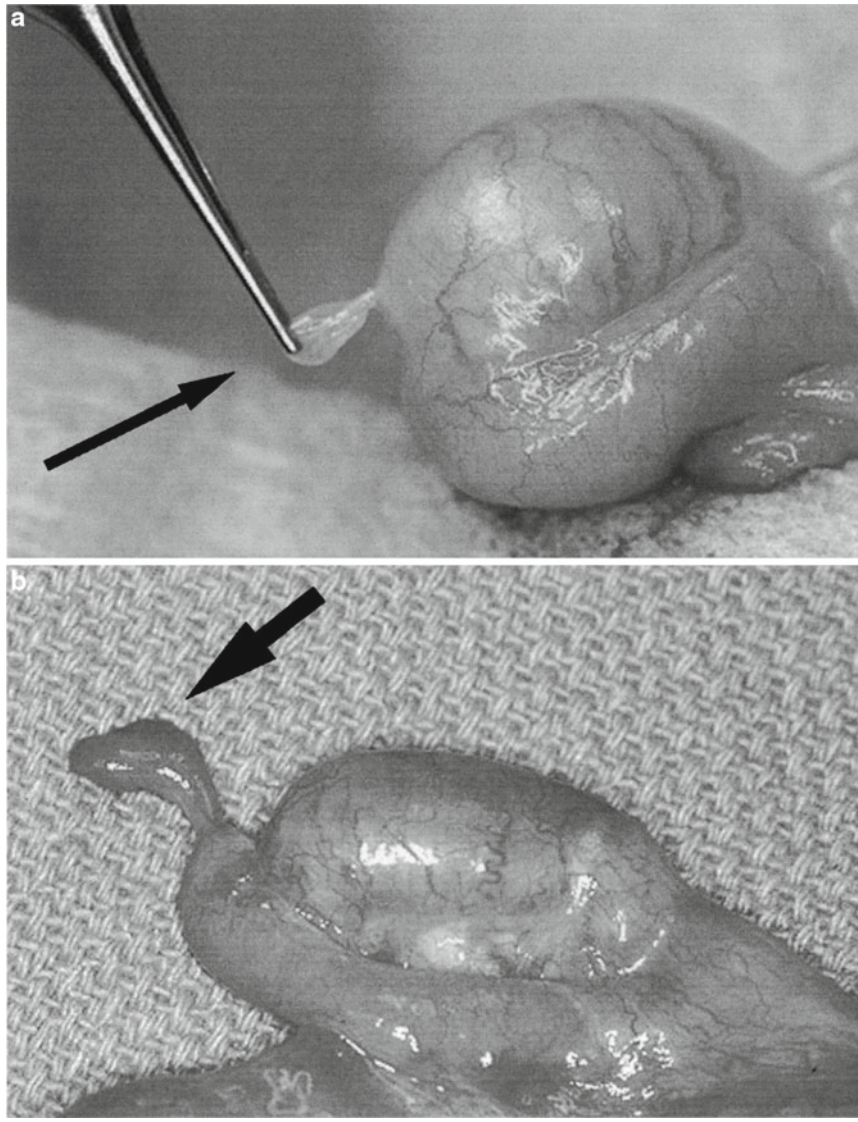

Fig. 16.4 (**a**) The appendix testis (*arrow*). (**b**) The appendix epididymitis (*arrow*). Both appendages are susceptible to twisting around their small vascular pedicle

gested that hormonal stimulation during puberty increases their size, making them more susceptible to twisting around their small blood supply.

Clinical Presentation

Patients with intravaginal testicular torsion typically present with acute onset of severe scrotal pain, frequently making physical examination difficult. Some patients may present with pain referred to the ipsilateral lower abdomen. Torsion can occur following trauma or athletic activity; however, in most cases the patient is awakened from sleep. Nausea and vomiting may be associated with testicular torsion; urinary symptoms such as dysuria and urgency are usually absent. Important signs of torsion include a firm testicle riding high in the scrotum, an abnormal transverse orientation of the testis, and the absence of a cremasteric reflex [2]. In many cases, acute hydrocele or marked scrotal edema develops

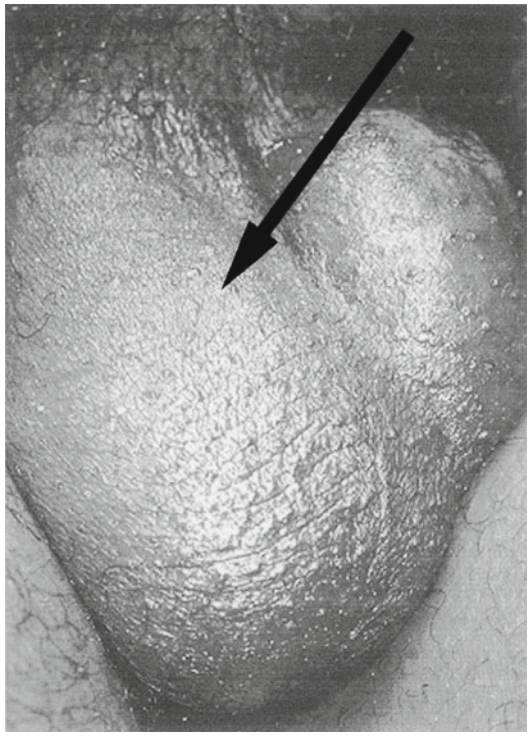

Fig. 16.5 The scrotum of a 14-year-old boy who presented with acute right testicular pain. The patient sought medical attention 12 h after the onset of pain. An acute hydrocele (*arrow*) has resulted, making palpation of the testis more difficult

when several hours have passed since the onset of the scrotal pain (Fig. 16.5). Fever and an elevated white blood cell count are not frequently associated with testicular torsion.

Intermittent testicular torsion has a similar presentation to that of intravaginal torsion, except that the episode is self-limited, with resolution of symptoms after the cord spontaneously untwists. Many who present with acute testicular torsion have a history of prior episodes consistent with intermittent testicular torsion. Those with intermittent torsion are likely to have normal physical exam at the time of evaluation, when the pain has resolved.

In contrast to intravaginal torsion, neonates with extravaginal torsion present with painless swelling and scrotal discoloration. It is often found incidentally on newborn examination, when a firm testis with an associated hydrocele is noted. Interestingly, associated scrotal erythema is not often present, but the overlying skin is discolored by the underlying hemorrhagic necrosis.

Table 16.1 Differential diagnosis for acute/subacute scrotum

Testicular torsion
Appendiceal torsion (testis or epididymis)
Epididymitis/epididymo-orchitis
Inguinal hernia (reducible or incarcerated)
Hydrocele
Trauma (mechanical, burns, or animal/insect bite)
Testicular neoplasms
Spermatocele
Varicocele
Dermatological lesions
Inflammatory vasculitis (Henoch–Schonlein purpura)
Idiopathic scrotal edema
Referred pain

Torsion of the appendix testis or epididymis can cause pain similar to that seen with intravaginal testicular torsion. However, the presentation for torsion of the appendix testis or epididymis can be quite variable, from an insidious onset of scrotal discomfort to acute severe scrotal pain. Consequently, it is often difficult to differentiate appendiceal torsion from other causes of acute scrotum (Table 16.1). At the earlier stages, the pain may be localized to the upper pole of the testis or epididymis, and a firm nodule can sometimes be palpated in this region of the scrotum. In some cases, the infarcted appendage can be seen through the scrotal skin as a blue dot, which is considered pathognomonic for appendiceal torsion. In the later stages, scrotal wall edema and erythema can develop, distorting the physical examination. The cremasteric reflex is usually preserved, and the testis should remain mobile.

In patients suspected of having testicular torsion on a clinical basis, prompt surgical exploration is warranted. Adjunctive radiological tests should only be obtained when their purpose is to confirm the absence of testicular torsion so that surgical exploration can be avoided. In these cases, color or power Doppler ultrasound or scrotal scintigraphy may be obtained. In ruling out testicular torsion, there is no absolute gold

standard. False negatives can occur with any of these modalities. The choice of which modality to utilize varies with institution, depending on local experience, availability, and reliability of the tests.

Color Doppler ultrasound studies can assess the anatomy of the scrotum and its content while determining the presence or absence of testicular blood flow (as measured by velocity). The sensitivity of color Doppler ultrasonography is reported to be as high as 90 %, with a specificity of 99 % [3]. Caution must be used in the interpretation of these studies because almost 40 % of patients, especially those younger than 8 years, may fail to demonstrate flow on the asymptomatic side [4, 5]. Power Doppler ultrasonography measures blood flow by detecting the number of red blood cells as opposed to the velocity of flow. Although blood flow is more consistently detected in younger children with power Doppler [4], evidence from animal studies suggested that power Doppler and color Doppler are equally efficacious in the detection of torsion [6].

Radionuclide imaging was originally the study of choice for ruling out testicular torsion. However, it only allows for the assessment of blood flow. Nussbaum et al. carried out a study in 46 patients presenting with acute scrotal pain and showed scintigraphy for testicular torsion to have a sensitivity of 78.6 % and a specificity of 90.6 % [7]. Hyperemia of the scrotal wall can give false impressions of testicular blood flow. In addition, it is difficult to image children with small scrotal sacs or testis using this study.

Treatment

Faced with a suspected diagnosis of testicular torsion, the patient should be taken to surgery without delay. Manual detorsion may be attempted if surgical intervention cannot be done for a period of time. After performing a cord block with local anesthetic, the testis should be turned caudal to cranial and medial to lateral [8]. If the first attempt is unsuccessful, the testis should be turned in the opposite direction. If the detorsion is successful, the pain should resolve immediately. However, this process is often very painful, and manual detorsion may not completely correct the obstructed blood flow. Consequently, surgical intervention is still required following manual detorsion.

Upon entry into the scrotum, the tunica vaginalis is entered and the testis is examined. The spermatic cord should be detorsed to restore blood flow. The affected testis should then be placed in a warm sponge and observed for several minutes to determine viability. This can be done while exploring the contralateral testis. In all cases, the contralateral testis must be fixed through orchidopexy. Following this, the affected testis is reevaluated first by color, and if it is returning to its normal coloration, orchidopexy is done. If the testis remains dusky, further evaluation can be done by incising the tunica albuginea and looking for return of fresh blood. If the testis continues to appear dusky and tunica albuginea incision produces no fresh blood, the nonviable testis should be removed.

There are several options for surgical fixation of viable testes. Traditionally, the testis has been fixed by placing a suture through the tunica albuginea and into the wall of the scrotum. However, recurrent torsion has been reported with this technique. Fixation can be accomplished in a transseptal fashion through a median raphe incision. The testis is secured to the median septum with three to four fine, nonreactive, nonabsorbable sutures. These sutures can be brought through the septum, enabling the contralateral side to be fixed concurrently. Alternatively, a dartos pouch can be created where fixation relies on scarification of the testis. An incision is first made transversely in the scrotum following the natural skin creases. The tunica vaginalis is then everted, and the testicle is placed into the dartos pouch. A nonabsorbable suture is used to secure the dartos tissue around the cord. This technique is advantageous in that complications such as abscess formation and tubular atrophy are uncommon. Anecdotally, there have been no reported cases of recurrent torsion with this technique. Intermittent torsion is corrected using either of the above techniques on a semi-elective basis.

Recent data suggests the existence of a compartment syndrome effect taking place in the

setting of testicular torsion. Kutikov et al. reported on three cases where incision of the tunica albuginea led to increased perfusion of a testicle that was not reperfusing following detorsion. Subsequent reapproximation of the tunica albuginea in these patients led to a return of testicular ischemia. In all cases, a tunica vaginalis flap or graft was used to cover the exposed seminiferous tubules and to keep intratesticular pressure low and maintain perfusion [9]. A study carried out by Figueroa et al. showed similar findings with regard to increased testicular compartment pressures in testes that had been detorsed intraoperatively. Perfusion was successfully increased when performing the tunica albuginea incision with tunica vaginalis flap. Their preliminary study included 65 patients, 11 of who underwent the tunica albuginea incision with tunica vaginalis flap. Their results suggest that 6 out of those 11 patients would have otherwise undergone orchidopexy [10].

The treatment of neonatal torsion is controversial. Some suggest that surgical exploration is unnecessary; others advocate immediate surgical exploration and fixation of the contralateral side. It is rare to salvage the affected testis in a patient with unilateral neonatal torsion. In addition, of more than 30 cases of bilateral neonatal torsion reported in the literature, only two testicles have been successfully salvaged [11]. The most important reason for exploration in our opinion is to prevent possible unilateral torsion from becoming bilateral anorchia. In the rare case of bilateral neonatal torsion, a more conservative approach can be taken. The newborn's general condition and anesthetic considerations should be evaluated to determine whether to proceed with surgical intervention.

The treatment of twisted testicular appendages is nonsurgical. If the diagnosis is certain, conservative therapy with limitation of activity and administration of nonsteroidal analgesics can be instituted. Most of the symptoms will dissipate once the acute changes of acute necrosis resolve. In rare instances, surgical exploration may be undertaken if conservative management fails. Simple excision of the torsed appendage is curative.

Epididymitis/Epididymo-Orchitis

Another common cause of an acute scrotum is inflammation/infection of the epididymis. The infection may also involve the testis (epididymo-orchitis). An uncommon diagnosis in children [12], several different etiologies are responsible, including infection, trauma, and anatomical abnormalities.

Bacterial infection is common in patients who are sexually active. However, viral agents such as mumps, coxsackie, echovirus, and adenoviruses have been identified in children with epididymitis [13, 14]. Traumatic causes include straining or lifting, for which a sudden increase in abdominal pressure causes reflux of sterile urine, leading to epididymal inflammation. Torsion of a testicular appendage can also lead to a reactive epididymitis.

Anatomical abnormalities and dysfunctional voiding are further causes of epididymitis. Other causes of epididymitis in children include insertion of an ectopic ureter into the seminal vesicle and bladder outlet obstruction such as posterior urethral valves or urethral stricture. Detrusor-sphincter dyssynergia, secondary to neurogenic and nonneurogenic bladder dysfunction, will lead to increased bladder pressures, with the possibility of sterile reflux. Finally, epididymitis may be associated with systemic diseases, including sarcoidosis, Kawasaki's disease, and Henoch–Schonlein purpura [15].

Clinical Presentation

The most common presenting symptoms include scrotal swelling, erythema, and pain. Epididymitis is usually an indolent process, but may present in a fashion similar to testicular torsion. Epididymitis is more likely in a patient with a past history of urinary tract infection, urethral catheterization, or urinary tract surgery. Although fever and urinary symptoms such as dysuria, urethral discharge, and hematuria are more common in patients with epididymitis than with testicular torsion, many patients with epididymitis may not have any of these symptoms.

On physical examination, localized epididymal or generalized scrotal tenderness may be found. The cremasteric reflex is usually preserved. Evaluation of the urine often demonstrates pyuria and bacteriuria; however, urine cultures may be sterile in 40 % of the cases [12, 15] because virus can also be an etiological agent.

Scrotal imaging can be used to help distinguish between epididymitis and torsion. In the cases of epididymitis, Doppler ultrasonography or radionuclide imaging demonstrates increased blood flow. On ultrasonography, the testis is often enlarged and has a reactive hydrocele.

Treatment

Epididymitis is treated with a combination of scrotal elevation, nonsteroidal anti-inflammatory agents, and antibiotics when appropriate. Limitation of activity, scrotal elevation, and application of heat or cold will help alleviate scrotal pain. Urethral instrumentation should be avoided.

In children with suspected epididymitis, a urinalysis and urine culture should be performed. In addition, a voiding cystourethrogram and a renal bladder ultrasound should be obtained to look for anatomical abnormalities such as ectopic ureter if a urinary tract infection is documented. If the above studies are normal, the child should be worked up for unrecognized dysfunctional voiding as a cause for reflux of urine into the epididymis. Treatment of epididymitis in adults is reviewed in detail in Chap. 9.

Testicular Trauma

Testicular trauma is an infrequent occurrence because of the mobility and position of the testicle within the tunica albuginea. The etiology is most often caused by a direct blow that compresses the testicle against the pubic bone [16] as a result of a sports injury or motor vehicle accident [17]. Blunt trauma accounts for 85 % of the cases; the remainder result from penetrating injuries [18]. There is a slight preponderance of injuries on the right side, possibly because of the higher riding position of the testicle [17]. The majority of patients are between 10 and 30 years of age.

Types of injuries include testicular contusions with hematoceles and hematoma, testicular rupture, and traumatic dislocation. Hematoceles result from bleeding into the tunica vaginalis; a hematoma develops from intratesticular bleeding. Patients who sustain testicular injury may also present with torsion. Hydroceles and pyoceles may present as delayed sequelae of an acute injury.

Clinical Presentation

In patients with testicular injury, the scrotum may be tense, edematous, ecchymotic, or fail to transilluminate. In these patients, there are often associated findings, such as nausea, emesis, and urinary retention. Because of the nature of the injury and the force required to compress the testicle, other abdominal or pelvic injuries, in particular pelvic fractures, should be ruled out. This is especially true for testicular dislocation, for which the scrotum will be well developed, but no testicle is palpable within the scrotum. In many cases, the diagnosis is delayed; however, palpation of the inguinal area will reveal a normal testicle.

Urethral injuries are also commonly associated with scrotal trauma. Bleeding at the urethral meatus in association with a pelvic fracture or perineal ecchymosis is an indication for obtaining a retrograde urethrogram. Traumatic torsion will present as a painful high-riding testicle, which may have a transverse lie. Scrotal pain and swelling in the presence of a fever and elevated white blood cell count several days after a traumatic event suggest the presence of a pyocele.

The most useful diagnostic tool in the evaluation of closed testicular trauma is ultrasonography of the scrotum. Guichard et al. carried out a study of 33 patients presenting with blunt scrotal trauma where they compared ultrasonographic findings to surgical findings. Rupture was suspected in patients whose scrotal ultrasound showed heterogeneous parenchyma and a loss of testicular contour. Sensitivity and specificity of ultrasound for testicular rupture were found to be 100 % and 65 %,

respectively [19]. Buckley and McAninch performed a study in 65 patients presenting with blunt scrotal trauma and reported a sensitivity of 100 % and specificity of 93.5 % for ultrasound diagnosis of testicular rupture [20]. Absence of testicular blood flow is indicative of traumatic torsion.

Treatment

Patients with penetrating trauma or ultrasound evidence of testicular rupture require immediate surgical exploration. If the diagnosis is uncertain and there is any possibility of an underlying testicular tumor, an inguinal approach is best; otherwise, a transverse scrotal incision is made. In the case of testicular rupture, the devitalized tissue is excised, and the capsule is repaired (Fig. 16.6a, b). Failure to repair these injuries can lead to persistent pain, abscess formation, and testicular atrophy.

Orchiectomy should be avoided when there is remnant functioning tissue. In the rare occurrence of complete traumatic amputation without scrotal avulsion, prompt microsurgical repair of the vessels can be performed. If this is not an option, orchiectomy should be considered. Autotransplantation into a subcutaneous thigh pocket can be attempted; however, the results to date have been disappointing, with atrophy and necrosis more common outcomes [21].

Dog bites to the scrotum are occasionally encountered. These wounds should be debrided, and the patient should be given broad-spectrum antibiotics and tetanus and rabies vaccinations. These wounds should only be closed in the absence of infection [22]. Traumatic torsion is corrected by surgical detorsion of the testicle, followed by the placement of the testicle in a dartos pouch. The testicle may be secured in place with a nonabsorbable suture. Testicular dislocation requires immediate surgical reduction. Although closed reduction may be attempted, it is associated with a high failure rate [23]. In addition, there is the possibility of torsion or testicular rupture associated with dislocation, which is best managed in an open fashion.

Evacuation of a scrotal or tunical hematoma is controversial. Open evacuation may lead to infection. However, failure to relieve the hematocele can lead to pressure-induced atrophy of the testicle. It is our policy when confronted with a tense subcapsular hematoma to open the tunica albuginea and drain the blood. Patients diagnosed with a mild contusion and no changes in testicular architecture are best managed with bed rest, scrotal elevation, and nonsteroidal anti-inflammatory agents.

Scrotal and Perineal Burns

Burns to the scrotum and perineum occur infrequently. Anatomically, the scrotum is protected by the thighs. In combination with the looseness of the scrotal skin and the retraction of the cord by the cremasteric muscles, these features help to protect the testicles. Isolated scrotal burns are uncommon, and most are seen in patients with more extensive burns [24]. Scald burns are more common in very young children, whereas flame or electrical burns affect older children.

Treatment depends on the type of burn incurred. Most first-degree and superficial second-degree burns respond to conservative treatment. Michielsen et al. [25] reported an 81 % success rate in treating these patients with physiological dressings and topical antimicrobials. Of these children, 14 % were treated with allografts, for an overall 95 % rate of wound healing. Patients with deep second- or third-degree burns will require more surgical procedures; however, those with deep flame or electrical burns suffer a dramatically high incidence of partial penile loss, testicular loss, and groin contractures [24]. The outcome of these patients is dictated by the severity of the initial injury.

Miscellaneous Causes of Acute Scrotum

Included in the differential diagnosis for the acute/subacute scrotum are hernias/hydroceles (Table 16.1). In children, a persistent processus vaginalis allows fluid or omentum/bowel to descend into the scrotum, resulting in a commu-

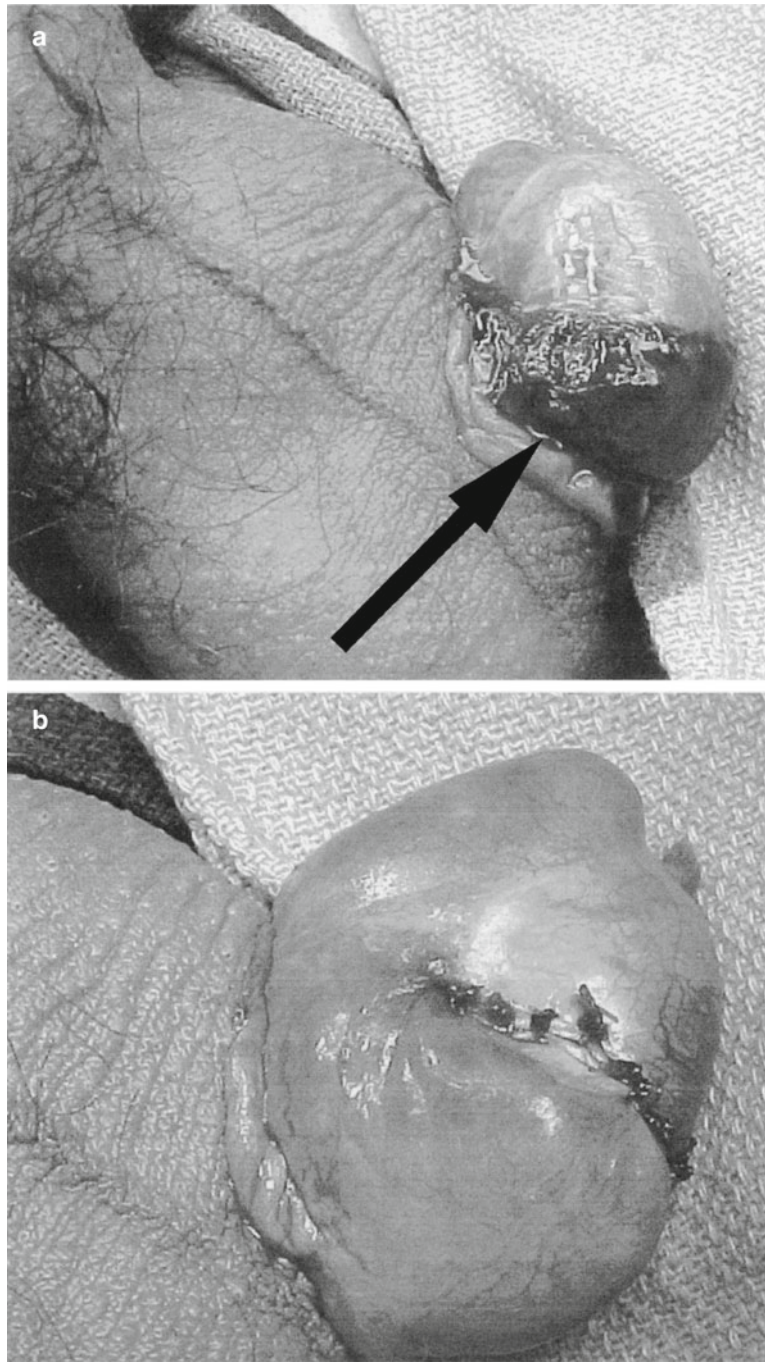

Fig. 16.6 (**a**) Traumatic rupture of the testicle with devitalized tissue (*arrow*). (**b**) The devitalized tissue has been excised and the capsule approximated

nicating hydrocele or hernia, respectively. In adults, hernia results from a weakness in the abdominal wall that allows its content to descend into the scrotum. When pain is present, bowel incarceration in a hernia sac should be considered. Prompt surgical exploration should be

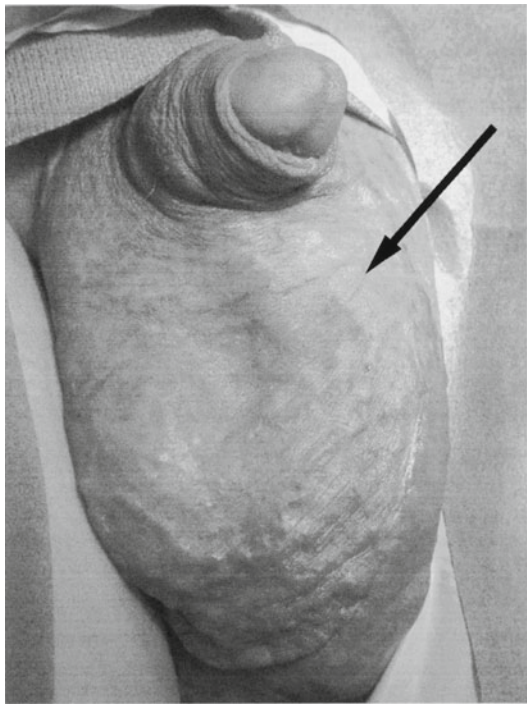

Fig. 16.7 A varicocele is noted above the left testis (*arrow*). Note the "wormlike" appearance of the varicocele that often dissipates on recumbence

undertaken. If the diagnosis is uncertain, Doppler ultrasonography may demonstrate bowel in the inguinal canal or scrotal sac. However, the ultrasonographic findings may be inconclusive. Given the serious, potential complication of ischemic bowel, inguinal exploration should be undertaken when an incarcerated hernia is suspected.

Varicocele results from dilation of veins of the pampiniform plexus of the spermatic cord. It is estimated that approx. 4.4–22.6 % of men have varicocele [26]. Its formation is partly caused by increased venous pressure in the left renal vein, collateral venous anastomoses, and incompetent valves of the internal spermatic vein. Occasionally, thrombosis of the varicocele results in inguinal or scrotal pain that is often relieved by assuming the supine position. In most cases, varicocele presents as a painless, compressible mass above or surrounding the testis (Fig. 16.7).

When symptomatic, treatment of varicocele is indicated. Ligation of the varicocele can be performed using a retroperitoneal, inguinal, or subinguinal approach. Alternatively, angiographic embolization can be performed to occlude the dilated veins. The choice of surgical technique is dependent on the surgeon's familiarity and consideration of potential complications, such as hydrocele formation, varicocele recurrence, and testicular atrophy.

Henoch–Schonlein purpura is a systemic vasculitis that can cause scrotal swelling and pain similar to that of torsion or epididymitis. The cause of the vasculitis is not known, but can involve the testis and/or epididymis [27]. Patients with Henoch–Schonlein purpura may have concurrent abdominal or joint pain, nephritis, hematuria, and purpura skin lesions. Scrotal involvement occurs in 35 % of patients with Henoch–Schonlein purpura. Typically, the scrotum is diffusely tender with generalized erythema. Urinalysis often demonstrates hematuria and occasionally proteinuria. Color Doppler ultrasonography or radionuclide scintigraphy shows increased blood flow. Scrotal involvement by Henoch–Schonlein purpura is self-limiting, and observation is usually indicated.

Like Henoch–Schonlein purpura, acute idiopathic scrotal edema is a self-limiting process that results in acute/subacute scrotal swelling [28]. Etiological factors include allergic or chemical dermatitis, insect bites, and trauma. Acute idiopathic scrotal edema is usually not associated with erythema, fever, urinary symptoms, hematuria, or pyuria. Pain is likely to be minimal, but pruritus may be significant. The normal testes can be palpated through the thickened scrotal wall. Examination of the perineum should be performed to rule out a contiguous process, such as a perineal abscess, which can also result in scrotal edema. When the diagnosis is unclear, Doppler ultrasonography should be done to evaluate testicular anatomy and blood flow. Acute idiopathic scrotal edema is self-limited and does not require any surgical intervention or antibiotic treatment.

Summary

The acute onset of scrotal pain should immediately raise the possibility of testicular torsion and requires immediate evaluation. History, physical

examination and selected laboratory studies generally allow a clinical decision for scrotal exploration for presumed torsion. High resolution scrotal ultrasonography allows confirmation of other diagnoses, but should not delay care for most cases of torsion. Torsion of the scrotal appendages, epididymitis, trauma, and a variety of other non surgical conditions may thus be identified and appropriately managed.

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Part IV

Acute Urinary Tract Obstruction

Renal Colic and Obstructing Kidney Stones: Diagnosis and Management

17

Joe Miller and Marshall L. Stoller

Introduction

Renal colic describes the acute, severe, and paroxysmal pain caused by obstruction of the urinary tract. Increased intraluminal pressure caused by urinary tract obstruction stretches mucosal nerve endings, resulting in visceral pain and smooth muscle spasm. Afferent pain impulses are then conducted via sensory fibers traveling with sympathetic nerves toward the spinal cord, often resulting in referred pain. Pain from the proximal ureter can be referred to the flank, costovertebral angle (CVA), ipsilateral testicle or ovary. Mid-ureteral pain may be referred to the lower abdomen, while pain from distal ureteral obstruction may be perceived in the suprapubic region, scrotum or labia (Fig. 17.1). Some afferent nerve fibers from the renal pelvis and proximal ureter follow the course of the vagus nerve as they approach the spinal cord, which may cause concomitant nausea and vomiting [1].

Pain perceived as renal colic may stem from a variety of urologic and non-urologic conditions, though the majority of cases are due to an obstructing ureteral stone. This chapter briefly reviews the differential diagnosis of renal colic and presents a concise overview of the presentation, evaluation, and management of patients presenting with renal colic resulting from renal calculus disease.

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Differential Diagnoses of Renal Colic

In the United States, approximately 8.5 million (7.2 %) of the 117 million emergency department visits in 2007 were due to abdominal pain [2]. The differential diagnosis for renal colic is broad and encompasses numerous organ systems and pathological mechanisms (Table 17.1). A thorough history and physical examination (and often adjunctive laboratory tests or radiological studies) are necessary to distinguish the mimics of renal colic from the true form.

Vascular Etiologies: Aneurysm, Infarction, Hemorrhage

The diagnosis of vascular etiologies of flank pain, including renal artery aneurysm, acute renal infarction, and adrenal or renal hemorrhage require a high level of suspicion due to subtlety of their presentations (for more detail see Chaps. 12 and 13). Renal artery aneurysms are present in approximately 1 % of the population and most commonly present with nonspecific clinical findings including microscopic hematuria, hypertension, and flank pain. Peripheral calcification of the aneurysm may be visible on plain X-ray, but computed tomography (CT) or angiography is often required

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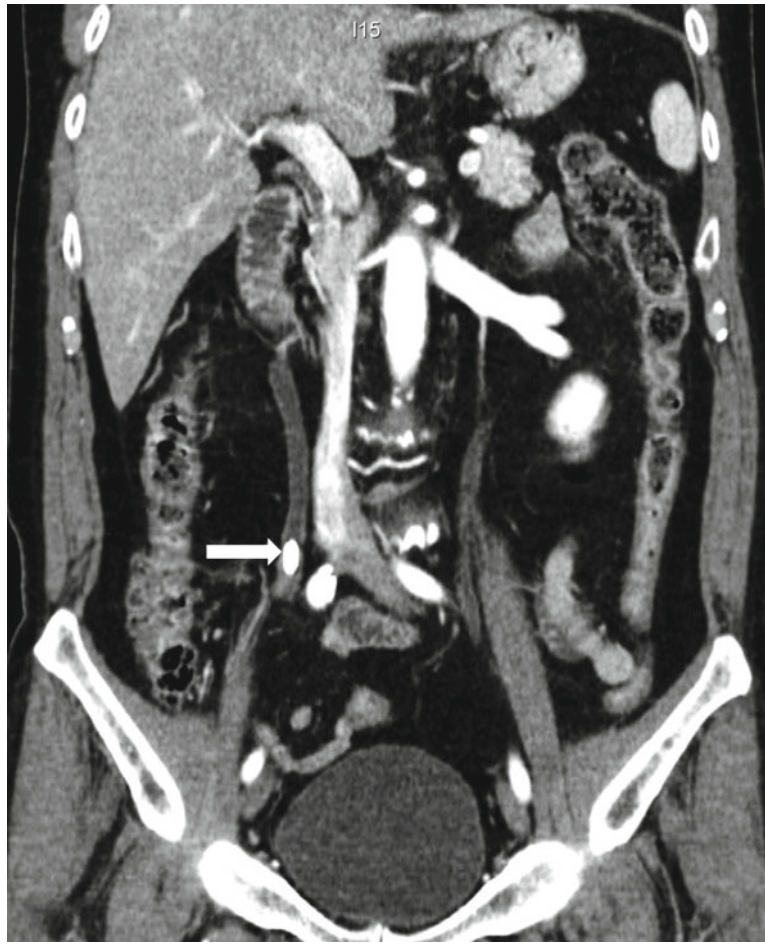

Fig. 17.1 Coronal noncontrast CT (NCCT) demonstrating a large right ureteral stone (*arrow*) causing proximal hydorureter

to confirm the diagnosis. Rupture of a renal aneurysm, though uncommon, may result in severe unremitting flank pain and shock [3].

Acute renal infarction also presents with symptoms similar to those seen in patients with an obstructing ureteral stone, particularly abdominal or flank pain, nausea, vomiting, fever, and chills. The embolus is attributed to atrial fibrillation in the majority of cases. Risk factors for renal infarction are the same as those of other thromboembolic events: hypertension, atherosclerosis, cardiac valvular disease, and coagulopathies such as sickle cell disease, Factor V Leiden, protein C and protein S deficiency. Nearly all patients with acute renal infarction will have significant elevation of serum lactate dehydrogenase. Angiography is the gold standard for diagnosis of renal infarction, though contrast-enhanced CT may also be used. Noncontrast CT (NCCT), commonly employed when ureteral stones are suspected, cannot reliably diagnose acute renal infarction [4].

Retroperitoneal hemorrhage may also present with symptoms of renal colic and may arise from the adrenal gland or the kidney. Non-traumatic acute adrenal hemorrhage may occur subsequent to a variety of underlying pathologic conditions including infection, coagulopathies, autoimmune disorders, or tumors. Presenting symptoms include flank/abdominal pain, nausea, vomiting, and low-grade fever. Patients with bilateral adrenal gland

Table 17.1 Differential diagnoses of renal colic

Renal
Calculi
Renal vein thrombosis
Renal pelvic clot obstruction
Papillary necrosis
Transitional cell carcinoma
Endometriosis
Fungal bezoar
Anatomic causes
Ureteropelvic junction obstruction
Crossed renal ectopia
Hematuria loin syndrome
Renal cell cancer
Polycystic kidney disease
Renal hemorrhage
Trauma
Pyelonephritis
Adrenal
Adrenal tumor
Adrenal hemorrhage
Ureteral
Calculi and causes listed under renal
Extrinsic compression
From tumor
From retroperitoneal fibrosis
From endometriosis
Teratoma
Ureterocele
Bladder
Cystitis
Calculi
Tumor
Seminal vesicle
Ejaculatory duct obstruction
Prostate
Prostatitis
Prostatic abscess
Vascular etiologies
Renal artery aneurysm
Abdominal aortic aneurysm
Aortic dissection
Iliac artery aneurysm
Gynecologic
Ectopic pregnancy
Ovarian vein thrombosis
Endometriosis
Ruptured ovarian cyst
Ovarian torsion
Gastrointestinal
Appendicitis
Diverticulosis
Diverticulitis
Inflammatory bowel disease
Meckel's diverticula
Volvulus
Peptic ulcer disease
Pancreatitis
Cholecystitis
Acute intermittent porphyria
Neuropathic pain
Referred pain
Spinal nerve compression
Munchausen's syndrome

hemorrhage or hemorrhage of a solitary adrenal gland may manifest symptoms of adrenal insufficiency such as mental status changes, fever, or hypothermia [5]. CT is most often the primary imaging modality used in the diagnosis of acute adrenal hemorrhage. Magnetic resonance imaging (MRI) is more useful in characterizing adrenal hemorrhage as acute, subacute or chronic. MRI can also determine if blood is the sole component of the hematoma, a finding indicative of a benign cause of the hemorrhage. *In neonates*, *abdominal ultrasound is the imaging modality of choice for diagnosis and follow-up of adrenal masses*, *including acute hemorrhage* [6]. The majority of data regarding treatment and outcomes of acute adrenal hemorrhage is drawn from the trauma literature but is generally applicable to non-traumatic hemorrhage as well. Treatment of adrenal hemorrhage is generally supportive in nature with close observation and medical management. Cases of refractory hemorrhage often can be managed with angiographic embolization [7].

Acute renal hemorrhage may also arise from an infectious process, malignancy, coagulopathy, or autoimmune disorder. Additionally, postoperative hemorrhage and hematoma formation are known complications of shockwave lithotripsy, partial nephrectomy, and renal biopsy. The presenting signs and symptoms of renal

hemorrhage are subtle in nature and, in addition to flank pain, include tachycardia, hypotension, nausea, vomiting and/or hematuria. *As in cases of acute adrenal hemorrhage*, *the initial management of acute renal hemorrhage consists of observation and supportive care*, *with selective angiographic embolization reserved for life-threatening arterial hemorrhage or failed conservative management*. With a success rate of 80–100 %, selective angiographic arterial embolization preserves the majority of renal function in otherwise normal kidneys and has few major or minor side effects. Open surgical exploration on the other hand often results in nephrectomy [8].

Intraperitoneal Etiologies

Flank pain may also originate from the organs of the gastrointestinal and reproductive systems. Small bowel obstruction, cholangitis, cholecystitis, pancreatitis, diverticulitis, and appendicitis commonly present with abdominal pain. A careful history and physical examination may differentiate these intraperitoneal causes from true renal colic, but cross-sectional imaging is often required for definitive diagnosis. *Obstetrical causes of flank pain must be ruled out in reproductive-age women*, *including potentially life-threatening ectopic pregnancy and ovarian torsion*.

Infectious Etiologies: Renal Abscess, Perirenal Abscess, and Pyelonephritis

Infectious etiologies of flank pain include renal or perirenal abscess, acute pyelonephritis, and emphysematous pyelonephritis. A renal abscess is a collection of purulent fluid confined to the renal parenchyma that is most commonly caused by ascending infection from the lower urinary tract. Rarely pyelonephritis or renal abscess may occur via hematogenous spread of gram-positive organisms. A perirenal abscess lies between the renal capsule and Gerota's fascia. *Escherichia coli* and *Klebsiella pneumoniae* are the most common causative organisms. The majority of cases occur in females and nearly half of all patients presenting with a renal or perirenal abscess have diabetes mellitus. Fever, chills, flank pain, and CVA tenderness are typical. Antibiotic therapy is curative only in a minority of patients, with most requiring percutaneous drainage or surgical intervention [9]. A more extensive discussion of the management of perinephric abscess is included in Chap. 8.

Acute pyelonephritis also arises from an ascending infection of the lower urinary tract. The vast majority of cases occur in women and a proportion of patients carry a diagnosis of diabetes mellitus. *E. coli* is the causative organism in 90 % of cases and most patients can be treated with oral antibiotics on an outpatient basis. *Patients diagnosed with acute pyelonephritis who fail to improve clinically after 72 h of antibiotic therapy should undergo further evaluation*, *including renal imaging for urinary obstruction or formation of an abscess* [10]. Although abdominal CT is the traditional modality of choice for renal imaging, bedside ultrasound (US) performed in the emergency department (ED) recently has been shown to be effective for detecting renal abscesses and other upper urinary tract abnormalities [11].

Emphysematous pyelonephritis represents an advanced and severe form of pyelonephritis in which the necrotizing infection produces gas within the renal parenchyma. This condition requires prompt diagnosis and treatment due to an overall mortality rate as high as 21 %. Uncontrolled diabetes is present in as many as 95 % of patients with emphysematous pyelonephritis. Alcoholism, drug abuse, and anatomic abnormalities are also frequent comorbidities. A radiologic diagnosis of emphysematous pyelonephritis can be made based on the finding of gas in the area of the renal shadow on plain abdominal radiography, or the finding of necrosis, gas, and/or fluid replacing areas of the normal renal parenchyma on CT. Treatment with intravenous (IV) antibiotics and percutaneous, image-guided drain placement results in preservation of the kidney in 70 % of cases [12].

Other Obstructive Etiologies

Renal colic may also be caused by obstruction of the ureter by processes other than renal calculus disease. Ureteropelvic junction (UPJ) obstruction, ureteral stricture, extrinsic ureteral obstruction, urothelial carcinoma, ureteral polyp, sloughed papilla, fungal bezoar, and blood clot occur far less frequently than obstructing ureteral stones, and as such the diagnosis of these entities often requires in-depth diagnostic procedures not commonly performed in the ambulatory care setting [13, 14]. These conditions are reviewed in detail in Chap. 18.

Evaluation of Patients with Renal Colic

History and Physical Examination

The history of present illness provides important etiological information in the evaluation of patients presenting with renal colic. Pain associated with an obstructing ureteral stone is usually described as severe and episodic, originating in the flank and radiating to the loin. Patients commonly report associated nausea and vomiting, fever, chills, irritative voiding symptoms, or gross hematuria. A report of pain that is not relieved by positioning is consistent with renal colic from an obstructing ureteral stone.

Other clues pointing to an obstructing ureteral stone may be found in the past medical and surgical histories. *A history of prior urinary calculus predicts average recurrence rates of 14*, *35*, *and 52 % at 1*, *5*, *and 10 years*, *respectively* [15]. Medical conditions known to be associated with urolithiasis include gout, renal tubular acidosis, homocystinuria, hyperparathyroidism, urinary tract infection, and inflammatory bowel disease. Surgical procedures such as gastric bypass, bowel resection, or interposition of bowel segments into the urinary tract may cause metabolic derangements and urolithiasis. Previous urinary tract surgery may suggest recurrent obstruction, urinary stasis, or the presence of a foreign body nidus of stone formation.

The patient's medication list should be closely reviewed for drugs known to form stones, either directly by precipitation in the urine, or indirectly by causing metabolic derangements leading to stone formation. Included among these stone-forming medications are diazides, protease inhibitors, triamterene, guaifenesin, magnesium silicate, phenytoin, and sulfa drugs [16–19].

On physical examination the patient is often ill appearing, nonstationary, and in obvious pain. Vital signs should be reviewed for temperature elevation and signs of hemodynamic instability. CVA tenderness or tenderness to palpation of the flank is consistent with renal colic.

Other physical findings suggestive of an underlying disease state associated with nephrolithiasis include the presence of a stoma indicating urinary or bowel diversion, gouty arthritis, or signs of recent large-scale weight loss consistent with gastric bypass surgery, malignancy, or other catabolic processes. Acute renal colic is not associated with an acute abdomen that is firm and rigid, nor is it associated with rebound tenderness.

Laboratory Studies: Urinalysis, Urine Culture, and Blood Culture

A midstream clean-catch urine sample should be obtained, inspected, and submitted for urinalysis, microscopic analysis, and urine culture with antibiotic sensitivities. Bedside inspection of the collected sample may yield one or more diagnostic clues based upon the turbidity, color, or smell. Cloudy urine may be indicative of pyuria, chyluria, hyperoxaluria, or phosphaturia. Numerous foods, medications, and pathologic states may discolor the urine, and darker color is typically an indication of increased urine concentration. A pungent odor is consistent with ammonia production by bacteria in infected urine, while a sulfuric smell may be attributable to the decomposition of cystine [20].

Dipstick urinalysis provides a rapid assessment of several physical and chemical properties of the sample that may be of diagnostic utility in patients with ureteral colic. Urine pH is typically 4.5–8.0 (average 5.8), but values within this normal range

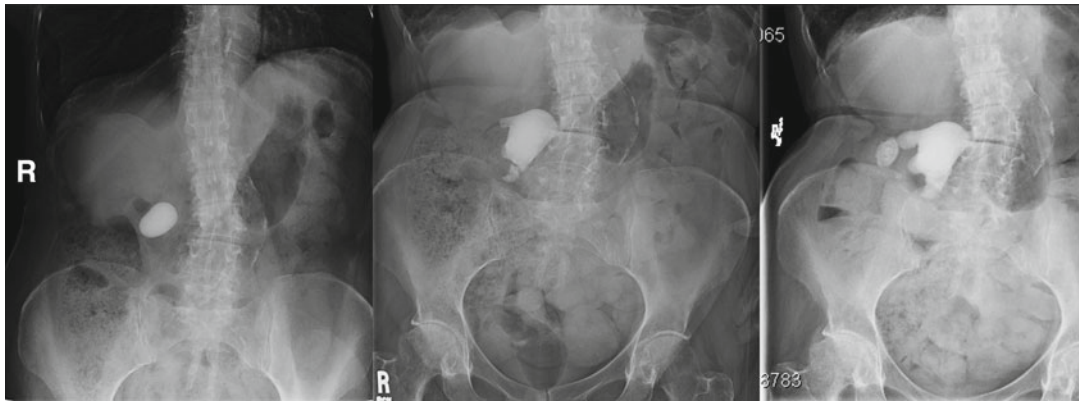

Fig. 17.2 Successive kidneys, ureters, bladder (KUBs) showing a large right renal ureteropelvic junction (UPJ) stone. After the patient failed to return for treatment, the stone grew to obstruct the right ureteropelvic junction

may be characteristic of patients who form specific types of renal calculi. *In patients with distal renal tubular acidosis* (*dRTA*), *a defect in hydrogen ion excretion results in systemic acidosis*, *alkaline urine*, *hypokalemia*, *hypocitraturia*, *hypercalcemia*, *and the formation of calcium phosphate stones* [21]. Uric acid and cystine stones will only form in acidic urine of pH <5.5, while struvite stones form in alkaline urine of pH >7.2. The vast majority of patients with calcium-based stones will have urine pH values between 5.5 and 7.2.

Hematuria, alone and in combination with imaging, has been examined as predictor of calculi. Among 138 patients presenting to the ED with flank pain, UA alone had a sensitivity of 69 % and a specificity of 27 %. When combined with helical CT, the sensitivity of the combination of the two tests was 91 % and the specificity was 91 %. It is important to note that 17 (31 %) of 54 patients with stones detected on CT did not have hematuria on UA, thus lack of hematuria does not exclude the diagnosis of calculi [22].

Microscopic analysis of voided urine may reveal crystals that are suggestive of stone composition. Hexagonal crystals are found in cystine stone-forming patients. Dumbbell-, hourglass-, or Maltese cross-shaped crystals are characteristic of calcium oxalate stones. Coffin-shaped crystals are found in concert with struvite (magnesium–ammonium–phosphate) stones, while brushite (calcium phosphate) stone crystals are long and thin, resembling needles [23].

In addition to urine culture, *blood cultures should be obtained from any patient who is at high risk of developing urosepsis*, *is febrile or has an elevated white blood cell count*.

Imaging Patients with Renal Colic

Definitive diagnosis of renal colic requires identification of calculi within the collecting system. Plain film radiographs of the kidneys, ureters and bladder (KUB), intravenous urography (IVU), NCCT, and ultrasonography (US) have all been employed with variable success, while MRI has been proven to be of little use in the evaluation of patients who present with symptoms of renal colic.

Plain Film Radiography

KUB has traditionally been used as a control film prior to the administration of oral and IV contrast agents for the evaluation of many acute presentations, including renal colic. In the evaluation of patients with renal colic these unenhanced images allow for the identification of calcifications and characterization of their size, shape, and relative location (Fig. 17.2). Limitations of the technique include obscuration of calcifications by overlying bony structures or bowel contents, limited soft tissue resolution, inability to localize calcifications in three planes and lack of functional information.

KUB, when used alone, has limited sensitivity and specificity in the detection of calculi in patients with renal colic. With sensitivities of 58–62 % and specificities of 59–67 %, depending upon the confirmatory test employed, their use has been supplanted by IVU and NCCT [24, 25].

Two recent studies suggest KUB may be useful as a less-costly and lower radiation exposure alternative for follow-up evaluation of ureteral stones. A comparison of KUB findings to NCCT results and CT scout radiographs of 140 patients with ureteral calculi revealed that 70 % of stones detected on NCCT were visible on KUB and 100 % of stones visible on the CT scout radiographs were visible on KUB [26]. A similar study of 163 patients found 100 % of stones seen on the CT scout radiography were also visible on KUB [27].

Intravenous Urography

From its initial description by Swick in 1929 until the relatively recent widespread availability of NCCT, IVU was considered the imaging modality of choice in the workup of patients presenting with flank pain and/or renal colic. IVU provides relative functional information, offers increased anatomic detail, and detects a wider spectrum of non-calculus causes of renal colic than the single static image obtained on KUB.

A rough estimation of overall and relative renal function can be ascertained from the duration and extent of contrast uptake and excretion from each kidney. Anatomic abnormalities such as ureteropelvic junction obstruction, nephroptosis, ureterocele, ureteral stricture, ureteral duplication, and renal ectopia also may be detected by IVU.

Calcifications overlying the urinary tract on KUB can be more accurately localized on the excretory phase of IVU when they are identified as intraluminal filling defects or when they define the distal extent of proximal ureteral dilation. Although IVU has several distinct advantages over KUB, it is not as accurate as NCCT in the detection of ureteral stones. A prospective randomized trial comparing the use of IVU to NCCT as the sole imaging modality for flank pain found the sensitivity and specificity in the detection of ureteral stones with IVU to be 75 and 91.7 %, compared to 85.1 and 98.1 % for NCCT [28].

Noncontrast Computed Tomography

NCCT emerged in the 1990s to eventually overtake IVU as the imaging modality of choice in the evaluation of patients presenting with renal colic. Numerous studies, some enrolling hundreds of patients, consistently report sensitivities and specificities of 94–100 % in the detection of ureteral stones [29].

Unlike KUB or IVU, NCCT allows for the accurate localization of calcifications within the urinary tract. When secondary findings such as hydronephrosis, proximal ureteral dilation, periureteral edema, forniceal rupture, or perirenal stranding are detected, NCCT also provides indirect clinical evidence of existing urinary tract obstruction or suggests recent spontaneous passage when stones are not seen [30, 31]. *Performing NCCT with the patient in the prone position allows differentiation of stones within the bladder from those within the intramural ureter* (Fig. 17.3) [32].

Indinivir, a protease inhibitor used in the treatment of human immunodeficiency virus, can precipitate in the urine and form stones that are not visible on NCCT. Secondary signs of ureteral obstruction on NCCT or a clinical history suggestive of ureteral stones in a patient prescribed a protease inhibitor should prompt further evaluation with an IV contrast-enhanced CT or IVU [33].

Phleboliths are calcified concretions within a vein wall that form as a result of thrombosis. Their presence along the course of the ureter, particularly within the true pelvis, may confound the detection of ureteral calculi on NCCT (Fig. 17.4). Plain radiographs of phleboliths often demonstrate a central area of radiolucency representing the original clot nidus, but this finding is only present on 63 % of pelvic phleboliths detect on NCCT [34]. Determination of mean attenuation

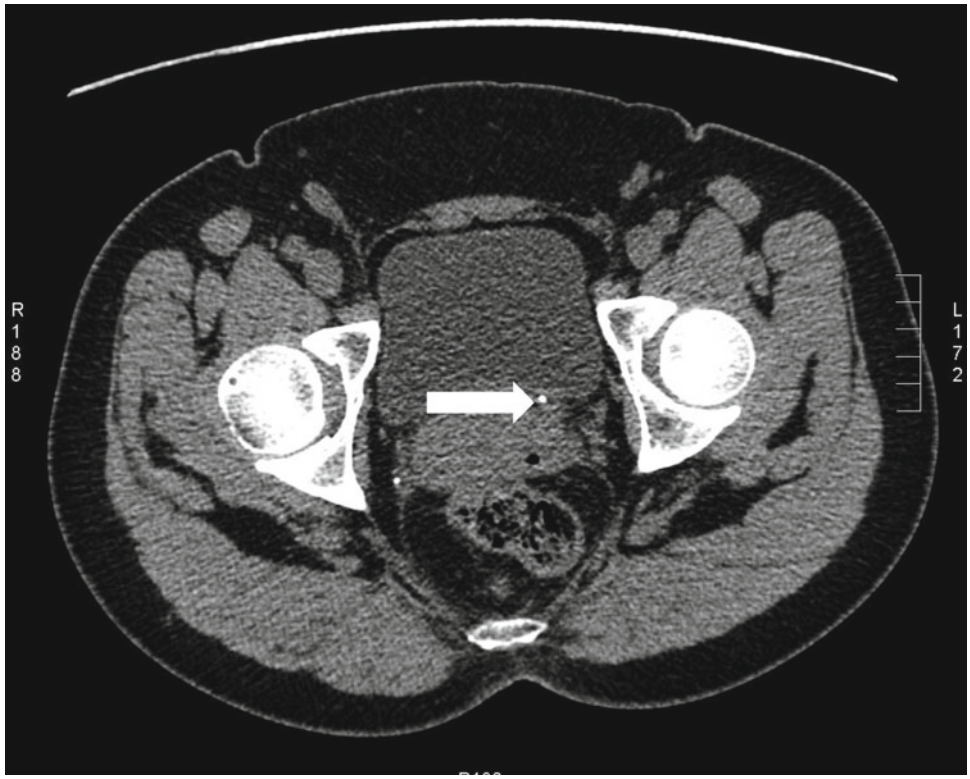

Fig. 17.3 NCCT revealing a stone lodged at the left ureteral orifice (*arrow*)

may allow for differentiation of pelvic phleboliths from ureteral stones. A retrospective review of 184 pelvic calcifications seen on NCCT found that none of the phleboliths had attenuation values greater than 287 Hounsfield units. Application of this threshold may aid in distinguishing pelvic phleboliths from distal ureteral stones [35].

Ultrasonography

US may be used as the primary diagnostic modality in the evaluation of patients presenting with symptoms of renal colic. US allows for the direct visualization of renal and proximal and distal ureteral calculi, as well as the detection of indirect findings supportive of the diagnosis, without the use of ionizing radiation. This makes US the preferred modality in the initial evaluation of children and pregnant patients.

Stones within the upper urinary collecting system appear as echogenic structures with a post-acoustic shadow (Fig. 17.5). Stones <5 mm may not reliably produce a post-acoustic shadow and thus may be indistinguishable from adjacent echogenic anatomic structures such as those of the renal sinus [36]. Ureteral calculi appear as hyperechoic intraluminal structures with posterior shadowing and are frequently associated with proximal ureteral dilation [37]. US has demonstrated sensitivities of 24–81 % and specificities of 82–100 % in the detection of renal calculi, and sensitivities of 11–93 % and specificities of 97–100 % for ureteral calculi [38]. Ultrasound may be more sensitive for stones in the proximal ureter and those near ureterovesical junction. Stones near the iliac vessels may be obscured by the increased acoustic impedence of surrounding tissue, but studies show >94 % of ureteral stones are located above or below this level [39].

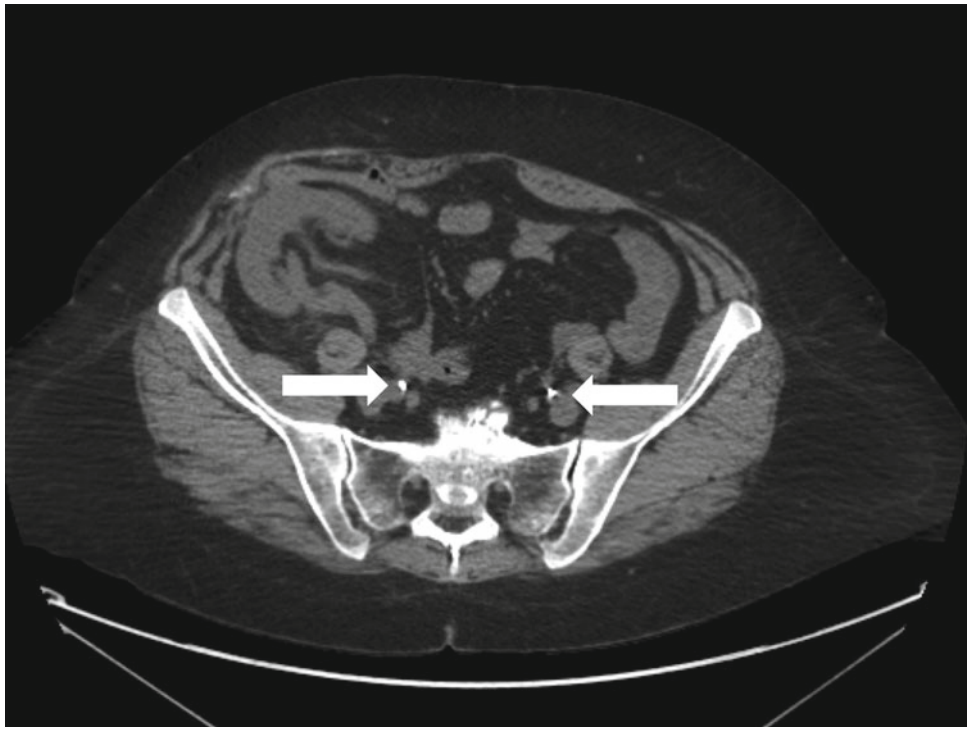

Fig. 17.4 NCCT (axial) showing a right ureteral stone in the ureter of a transplant kidney *(arrow)* and a left pelvic phlebolith *(arrow)*

Medical Management of Patients with Renal Colic due to Renal and Ureteral Calculi

Introduction

Medical management may be the preferred course of treatment when urgent intervention for ureteral colic is not indicated, or when definitive management is not practical. The medical management of renal colic is directed at mitigating, through pharmacologic intervention, one or more of the complex physiologic processes responsible for the symptoms associated with urinary tract obstruction. The therapies used in medical management are intended to ameliorate these symptoms, facilitate spontaneous passage of ureteral calculi, and relieve obstruction in cases on upper urinary tract infection. *The majority of ureteral stones will pass spontaneously*. *Medical management*, *therefore*, *is generally the preferred treatment for patients who have mild to moderate symptoms and who have stones <1 cm*, *in the absence of complete obstruction with concurrent urinary tract infection*.

Coll et al. found that 67 % of ureteral stones passed spontaneously with a near-linear inverse relationship between stone size and spontaneous passage rate. Stones of 1, 3, 5, 7, and 9-mm had spontaneous passage rates of 87 %, 83 %, 60 %, 47 %, and 33 %, respectively. A relationship also exists between stone location at time of presentation and passage rate. Stones less than 4 mm located in the proximal ureter had a spontaneous passage rate of 47 %, compared to an 80 % passage rate for stones of the same size located in the distal ureter. However, stones as small as 2 mm and located as distally as the ureterovesical junction failed to pass in some cases. This suggests there are other factors that may influence the likelihood of spontaneous stone passage [40]. The presence of secondary signs on NCCT may also predict the presence of concurrent lesions such as ureteral strictures or fibroepithelial polyps, which can impede the passage of stones. Hydronephrosis, perinephric fat stranding, and evidence of ure-

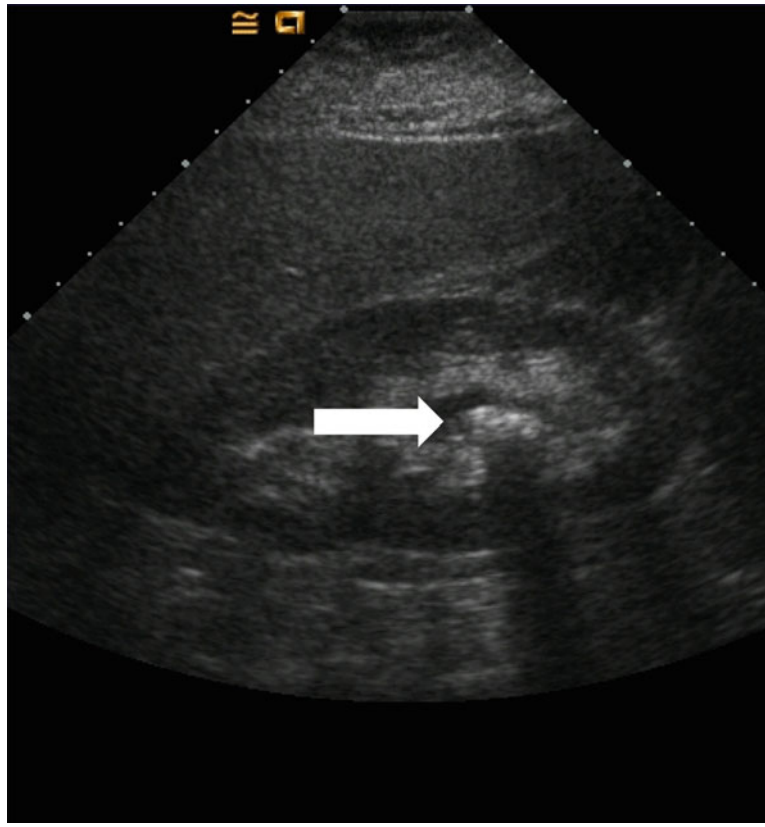

Fig. 17.5 Ultrasound (US) of right kidney showing stone in lower pole (*arrow*) with posterior acoustic shadowing

teral wall edema ("tissue rim sign") were present on initial CT scan in 30 cases of small (<5 mm) distal stones that failed to spontaneously pass. Follow-up ureteroscopy for these stones revealed severe ureteral edema in 9 (30 %), ureteral stricture in 5 (16.7 %), and ureteral polyps in 4 (13.3 %). *Based on these findings, patients with secondary signs on initial CT scan, and in particular a high-grade tissue rim sign, may benefit from earlier definitive treatment instead of expectant medical management* [41].

The time interval from diagnosis to stone passage is an important consideration when implementing medical management. Miller and Kane found 95 % of stones ≤2 mm passed in 31 days while 39 days were required for 95 % of stones 4–6 mm to pass. Significant combined predictors of stone passage include laterality (stones on right were more likely to pass spontaneously), proximity to the ureterovesical junction, and stone size ($p=0.012$). The average interval of observation to intervention was 24.2 days [42]. *Stone size and location should be used to guide the decision of when or if to initiate definitive management in lieu of medical management*.

Narcotics and Nonsteroidal Anti-inflammatory Drugs

Morphine, a naturally occurring alkaloid found in opium, has historically been the drug of choice for pain relief in cases of renal colic due to an obstructing ureteral stone. It is also the drug to which the potency and efficacy of other narcotics, including the synthetic opioids, are classically compared.

Three major opioid receptors, μ, κ, and δ, have been identified, via molecular cloning, in the human nervous system. Activation of these transmembrane receptors by endogenous opioids (endorphins, dynorphins, enkephalins) or opioid medications, initiates an intracellular cascade that ultimately results in decreased neuronal transmission of pain. The μ receptors in the brain and spinal cord are activated by morphine and most other opioids to facilitate relief of visceral and somatic pain, asserting an indirect effect to relieve renal colic [43]. There is also evidence that narcotics including fentanyl, pethidine, and its major metabolite norpethidine, facilitate relaxation of human ureteral muscle in vitro, and thus also have a direct effect on the underlying mechanisms of renal colic [44].

The use of narcotics is limited by common side effects including respiratory depression, constipation, nausea, tolerance, physical dependence, and abuse. Their analgesic effects are often augmented or supplanted by the use of nonsteroidal anti-inflammatory drugs (NSAIDs).

NSAIDs inhibit the synthesis of prostaglandins by blocking the action of the enzyme cyclooxygenase (COX). Two forms of COX have been identified. COX-1 is constitutively expressed and is required for the normal physiologic functioning of various tissues in multiple organ systems. The inducible form, COX-2, is selectively expressed in inflammatory conditions [45]. The resulting prostaglandins induce spontaneous ureteric muscle activity and increase the phasic contraction and tension in the human ureter. NSAIDs such as indomethacin and ketorolac inhibit the enzymatic action of both COX-1 and COX-2, reduce prostaglandin production, and in turn nearly abolish ureteral contractions to directly reduce the cause of pain associated with ureteral obstruction [46]. Nonselective inhibition of both COX-1 and COX-2 also results in the potent inhibition of prostaglandins, including those responsible for normal physiologic function of the gastrointestinal tract and the kidney. This widespread inhibition of prostaglandins synthesis results in unwanted side effects. The subsequent development of COX-2 selective agents allows selective inhibition of inflammation induced prostaglandin production without these gastrointestinal and renal side effects.

Concerns over cardiac side effects prompted a FDA-issued Black Box warning that has limited the use of selective COX-2 inhibitors in the treatment of renal colic [47]. NSAIDs such as ketorolac, however, are still widely used in the treatment of renal colic. *When used alone and in combination with narcotics*, *ketorolac provides superior pain relief*, *allows earlier hospital discharge and causes less cognitive and functional impairment than narcotics alone* [48, 49]. Though they are effective in reducing the pain of ureteral obstruction, NSAIDs have not been shown to affect the spontaneous stone passage rate [50].

Corticosteroids

Corticosteroids inhibit prostaglandin synthesis and reduce inflammation by interfering with de novo enzymatic protein biosynthesis via gene regulation [51]. The presence of a stone in the ureteral lumen results in submucosal edema, which may impede spontaneous stone passage [52]. Corticosteroids decrease this edema to facilitate stone passage and may directly reduce stretch-induced contractility and motility of the ureter to decrease pain [53, 54]. Corticosteroids *administered in combination with alpha-adrenergic antagonists* (*discussed below*) *significantly increase the spontaneous stone passage rate and decrease the need for analgesics compared to either medication alone* [55].

Alpha-Adrenergic Antagonists (α-Blockers)

Calcium-mediated contraction of ureteral wall smooth muscle is caused by stimulation of α_1-adrenergic receptors (ARs). The relative density and distribution of the α_1-AR subtypes is variable, but overall expression and receptor density is greatest in the distal ureter [56]. Numerous large-scale randomized studies have shown an increase in the spontaneous stone passage rate in patients treated with tamsulosin, a selective α_{1A}

antagonist. Among patients with distal ureteral stones ≤10 mm, those randomized to receive 4 weeks of 0.4 mg tamsulosin daily had a spontaneous stone passage rate of 77 %, compared to the 50 % spontaneous stone passage rate of the placebo group ($p=0.002$) [57]. Benefits of α-blocker therapy confirmed by similar trials include decreases analgesic use, decreased need for hospitalization, and a decrease in the stone passage interval [58]. Guidelines published in coordination by the American Urological Association and European Association of Urology (AUA–EAU) support the use of α-blocker therapy for the medical management of ureteral calculi ≤10 mm [59]. Medical explusion therapy (MET), utilizing NSAID, selective α_{1A} antagonist, with or without corticosteroids is now the standard of care to help facilitate the spontaneous passage of ureteral stones.

Calcium Channel Blockers

Calcium channel blockers (CCB) inhibit the contraction of ureteral smooth muscle by blocking voltage-operated calcium channels, preventing the influx of extracellular calcium. Early randomized studies showed a decrease in ureteral stone passage interval and increase in stone passage rates among patients treated with the CCB nifedipine when compared to patients receiving placebo, but more recent studies have demonstrated the clearly superior effect of α-blockers [60, 61]. The AUA-EAU guideline panel concluded that in the medical management of ureteral stones "…the positive impact of nifedipine is marginal [59]."

Anticholinergics

Stimulation, by acetylcholine, of muscarinic receptors in the wall of the urinary bladder causes contraction of the detrusor muscle during normal physiologic voiding. The spurious activation of these receptors has been implicated in the pathologic syndrome of overactive bladder (OAB), and muscarinic receptor antagonists such as oxybutynin and tolterodine have been widely used to safely and effectively treat OAB. The distal ureter travels through a tunnel of detrusor muscle as it approaches the ureterovesical junction. Some investigators have hypothesized that anticholinergic medications may be of use in the treatment of ureteral stones via their effect on the portion of the detrusor through which the ureter passes. Studies have shown that although anticholinergic medications may relieve some of the symptoms associated with ureteral stones, they do not decrease stone passage intervals or increase spontaneous stone passage rates [62, 63].

Alternative Treatments

Trigger point injection of local anesthetics such as lidocaine has been proven, in at least one randomized trial, to be superior to intravenous administration of anti-spasmotic and NSAIDs combination [64]. The trigger point is located by gently palpating the ipsilateral area between the iliac crest, costal margin, and vertebral spine until an area of significant tenderness is encountered. Injection is then made subcutaneously in this area to achieve a total treated area of 3–4 cm in diameter. Significant reductions in pain have been observed within 30 min [65].

Local active warming, the application of heat packs or electric heating blankets, has been shown to be effective in the treatment of pain associated with acute low back pain and acute cholecystitis [66, 67]. The application of a carbon fiber electric heating blanket (42 °C) to the back and abdomen during emergency transport has been shown to significantly reduce the associated pain, anxiety, and nausea of patients with renal colic [68].

Acupuncture has been employed in the symptomatic relief of renal colic associated with obstructing ureteral stones. When compared to the intramuscular injection of non-opioid analgesics, acupuncture was shown in a small study to provide more effective and rapid pain relief with less side effects [69].

Additional Considerations

The role of aggressive hydration, either oral or intravenous, remains controversial in the treatment of patients with ureteral stones. While volume resuscitation may be indicated in patients suffering from concomitant vomiting, or required as a supportive measure in septic patients, the utility of increasing fluids intake to facilitate stone passage is not supported by clinical evidence and is not recommended [70, 71]. All patients with ureteral stones treated with medical management should be instructed to strain their urine and to retain any stones or stone fragments. Chemical composition analysis of these specimens may reveal the etiology of stone formation and direct preventive measures, but this analysis tends to be less accurate with mixed-composition stones than with pure stones [72].

Close follow-up is required of patients with ureteral stones managed medically. Serial imaging and measurement of serum creatinine allows identification of worsening hydronephrosis and renal impairment caused by asymptomatic "silent obstruction." Among patients managed medically for an obstructing ureteral stone, 28 % suffered from impaired renal function and required intervention despite being asymptomatic [73].

Urgent Intervention in Patients with Renal Colic

Patients with renal colic require urgent intervention in the setting of intractable pain or vomiting, urinary tract infection with obstruction, fever, anuria, renal failure or obstruction of a solitary or transplanted kidney. The goal of urgent intervention is to relieve urinary obstruction or facilitate stone passage, thereby protecting renal function, facilitating drainage of infected urine, and ameliorating pain, nausea and vomiting. Commonly employed techniques for bypassing ureteral obstruction include retrograde ureteral stenting and percutaneous nephrostomy tube placement.

Retrograde Ureteral Stent

Retrograde ureteral stenting is accomplished via cystoscopy and carries the associated risks of that procedure including infection, anesthesia-related complications, and injury to the urethra, bladder, and/or ureter. In addition, placement of a ureteral stent requires the initial placement of a wire, and subsequent placement of the stent itself, past the obstructing ureteral stone/s. Although this may be difficult or impossible in cases of high-grade ureteral obstruction, studies have shown an overall success rate of >90 % [74, 75]. Indwelling ureteral stents have the advantage of draining urine directly into the bladder, obviating the need for an external collection device, but are frequently associated with irritative voiding symptoms and decreased quality of life [76].

Percutaneous Nephrostomy

Percutaneous nephrostomy tube placement bypasses an obstructing ureteral stone proximally and may be successful in cases where high-grade obstruction prevents retrograde ureteral stent placement. Urine is drained into an external collection device which, in the cases of coexisting urinary tract infection, has been shown to significantly reduce the mortality associated with subsequent gram-negative septicemia, compared to retrograde ureteral stent placement [77]. Percutaneous nephrostomy tube placement appears to have a lower overall cost, results in fewer irritative voiding symptoms, and a decreases need for analgesic medication, compared to retrograde ureteral stenting [78–80].

Percutaneous nephrostomy tube placement should be reserved for those patients where internal double J stent placement is impossible or unsuccessful, or when an urologist is unavailable. Many urologists will proceed directly to a percutaneous nephrostomy tube placement after initial attempts at double J stent placement are unsuccessful; this can be performed by an urologist or an interventional radiologist. The percutaneous nephrostomy tube placement can be

placed under ultrasonic guidance and fluoroscopic confirmation and does not routinely require a general anesthetic.

Urgent Intervention in Pregnancy

Renal colic in pregnancy is associated with hypertension, preeclampsia, and premature labor. Expeditious diagnosis and effective management is required to mitigate these risks to the mother and unborn child [81]. Ultrasound may be used to evaluate pregnant patients presenting with renal colic. In equivocal cases KUB, limited IVU, MRI, or low-dose NCCT may be used [82]. In the absence of an absolute indication for intervention (intractable pain, sepsis, solitary kidney, progressive renal insufficiency), medical management is the preferred course of treatment in pregnant patients with renal colic from an obstructing ureteral stone. Traditional MET is not routinely used in pregnant patients. As in nonpregnant patients, options for intervention include retrograde ureteral stenting or placement of a percutaneous nephrostomy drainage tube. Ultrasonic guidance may be used in lieu of fluoroscopy for both retrograde ureteral stent placement and nephrostomy tube placement. Ureteral stents are prone to encrustation during pregnancy and may require replacement as often as every 4–8 weeks. Compression of the bladder by the gravid uterus may increase the severity of the irritative voiding symptoms commonly associated with indwelling ureteral stents [82]. Pregnant women will frequently direct their treatment and many would rather have a percutaneous nephrostomy tube placed rather than any form of retrograde urologic intervention.

Definitive Treatment of Patients with Renal Colic

When medical management fails, or the impetus for urgent intervention has resolved, definitive treatment of an obstructing ureteral stone is generally undertaken on an elective outpatient basis. The modality of treatment depends on clinical parameters such patient body habitus, stone size and location, the availability of specialized equipment or facilities, the experience and preference of the surgeon, and the individual patient's desires and risk tolerance. Extracorporeal shock wave lithotripsy (SWL) and ureteroscopy (URS) are the two most common means of definitively treating ureteral stones.

Extracorporeal Shock Wave Lithotripsy

SWL provides a noninvasive means of treating renal and/or ureteral calculi by fragmenting stones into pieces small enough to subsequently pass spontaneously. Shock waves produced by an external shock wave generator are first focused and then directed, via fluoroscopy or ultrasound, to the target stone via an energy-conserving coupling medium. The success rate of SWL depends on numerous factors including stone size, location, and composition, body mass index, and skin-to-stone distance [83–85]. The risk posed by the high-energy shock waves of SWL may preclude its use in patients with untreated urinary tract infection, uncorrected coagulopathy, renal artery aneurysm, or aortic aneurysm. Additionally, SWL should not be performed in the setting of distal urinary tract obstructions, such as ureteral or urethral stricture, which may impede passage of stone fragments. The use of SWL in pregnancy should be avoided due to the potential for damage to the fetus [86].

Ureteroscopy and Intracorporeal Laser Lithotripsy

Rigid, semi-rigid, and flexible ureteroscopy may be employed with the addition of a variety of instruments to accomplish the removal of ureteral stones. Among the tools in the urologist's armamentarium are ureteral dilating balloons, stone retrieval baskets, and lithotripters of various energy sources.

Ureteral dilating balloons, available in diameters of 4–10 mm, and in lengths of 4–10 cm, are used to dilate the ureteral orifice to permit ureteroscopy,

facilitate placement of a ureteral access sheath, or to simply allow for intact stone removal.

Modern stone retrieval baskets are constructed from nickel-titanium (Nitinol) and are available in tipless configurations that allow opening of the basket beyond the stone in a relatively atraumatic fashion. The Nitinol construction is more durable than the wire-based predecessors and the enhanced flexibility allows for greater deflection of flexible ureteroscopes [87].

Stones that are too large to be removed from the ureter intact can be fragmented utilizing a variety of energy sources. Laser lithotripsy has largely replaced all other modalities including ultrasonic, electrohydraulic, and pneumatic lithotripsy in the treatment of ureteral stones. The Holmium:Yttrium-Aluminum-Garnet (Ho:YAG) laser fragments stones by vaporizing the adjacent fluid and subsequently creating a bubble that conducts laser energy directly onto the surface of the stone. This direct application of laser energy results in greater fragmentation and smaller resultant fragment size than earlier laser lithotripters [88, 89].

Summary

Renal colic describes the acute, severe, and paroxysmal pain caused by obstruction of the urinary tract. Pain perceived as renal colic may stem from a variety of urologic and non-urologic conditions with a broad differential diagnosis encompassing numerous organ systems and pathological mechanisms. Careful evaluation with a thorough history and physical examination, as well as laboratory and imaging studies, is necessary to exclude life-threatening conditions and definitively diagnose an obstructing ureteral stone. Most cases can be treated expectantly with medical management including medical expulsive therapy, but urgent intervention with retrograde ureteral stenting or placement of a percutaneous nephrostomy tube may be necessary. In the post-acute setting, definitive treatment may be accomplished on an outpatient basis utilizing a modality commensurate with the clinical parameters, equipment and facility availability, and the preferences of the physician and the patient.

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Nonurolithic Causes of Upper Urinary Tract Obstruction

18

Roger K. Low

Introduction

Renal colic caused by urolithiasis is the most common cause of upper urinary tract obstruction that prompts patients to visit an acute care facility. Patient care providers must be aware of other less-common causes of upper urinary tract obstruction presenting similar to urinary stones. Although few of the clinical entities discussed in this section are true "urologic emergencies," a physician's familiarity with all of them will be helpful in the evaluation of any patient thought to have renal colic.

Clinical Presentation

Conditions capable of causing upper urinary tract obstruction other than urolithiasis rarely present with classic symptoms of acute renal colic. This is due to the chronic nature of the conditions and the development of symptoms over a long period of time. Free floating luminal objects capable of obstructing the ureter, like kidney stones, often do result in renal colic, presenting with ipsilateral flank pain radiating into the groin and associated nausea and vomiting. Symptoms of renal colic are common with the passage of blood clots, sloughed renal papillae, and fungal bezoars. Patients with congenital obstruction of the upper urinary tract may give a history of intermittent colic prompted by heavy fluid intake or diuresis. The remaining etiologies are often asymptomatic or present with less acute symptoms of pain, incidental hydronephrosis, azotemia, or change in serum creatinine.

The evaluation of any patient suspected of renal colic begins with a detailed history and physical examination. Patients with hematuria and clot colic should be questioned about coagulation disorders, use of medications affecting clotting, urologic instrumentation, and history of tobacco usage which is the most common risk factor for urothelial cancer. Patients found to have upper urinary tract obstruction unrelated to stones should be queried on medical conditions known to predispose to papillary necrosis such as diabetes, sickle cell disease, past infections, and medications.

Laboratory Evaluation

The initial evaluation and treatment of any patient suspected of having upper urinary tract obstruction is dictated by the presence/absence of associated urinary tract infection (UTI), overall renal function, and efficacy of symptomatic relief with medications. Any patient demonstrating evidence of a complicating UTI, renal compromise or symptoms intractable to medical management require

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either hospitalization and/or acute intervention to relieve their obstruction. Therefore, the initial laboratory evaluation to evaluate any patient suspected of renal colic includes urinalysis (and culture if infection suspected), complete blood count, and basic serum chemistries.

Imaging

The imaging of patients suspected of having renal colic has dramatically changed over recent years. Historically, patients suspected of renal colic were imaged with an intravenous pyelogram (IVP). Advances in computed tomography (CT) quickly led to the widespread use of CT imaging of patients in the acute care setting. CT offers prompt evaluation of the urinary tract and abdominal/pelvic organs making it useful in evaluating any patient with unexplained abdominal or flank pain. Patients suspected of having renal colic due to stones are frequently imaged with noncontrast CT imaging without the administration of intravenous or oral contrast (CT-KUB). The accuracy of CT-KUB in diagnosing urinary stones is reported to be 97 % [1]. Although CT has proven efficacy in diagnosing urolithiasis, its utility in evaluating less common etiologies for upper urinary tract obstruction is less clear but likely equally beneficial.

There are growing concerns over the utilization of CT imaging due to its high cost and radiation exposure relative to other imaging modalities. All pediatric patients and pregnant women should first be evaluated with ultrasonography to avoid radiation exposure. Excessive radiation exposure has been linked to the development of secondary malignancies and fetal developmental disorders especially exposure during the first trimester of pregnancy. In one study, the mean radiation exposure associated with CT imaging averaged 6.5–8.5 mSv depending on the protocol and type of CT [2]. Low radiation dose protocols capable of reducing radiation exposure while maintaining image quality are under investigation.

Imaging of patients suspected of renal colic in the acute care setting is best managed by either the combination of conventional KUB and renal ultrasonograpy or CT imaging. Conventional radiography in combination with ultrasonograpy will provide enough information to diagnose and initially manage the majority of patients while minimizing their radiation exposure. CT imaging however has been shown to be slightly more sensitive and specific while providing additional information regarding non-urologic entities that may mimic renal colic [3]. Most of the conditions described below can be diagnosed by noncontrast CT imaging. The use of intravenous contrast may be required if delineation of the ureteral lumen or its contents are necessary. Intravenous contrast administration is recommended in any patient with unexplained hematuria or if there is a suspicion of a ureteral stricture. The diagnostic evaluation for hematuria requires evaluation of the upper urinary tract collecting system for the presence of urothelial carcinoma especially in older patients or patients with a history of tobacco usage. Counseling of patients with ureteral strictures requires knowledge of the length and severity of the stricture which are important prognostic factors. Any patient being considered for IV contrast administration should be questioned about history of past contrast exams, previous contrast reactions, and knowledge of renal function. Patients with past anaphylaxis resulting from IV contrast should not be imaged again in this manner. Patients with milder reactions can be given prophylactic medications to reduce chances of a contrast reaction. Common medication regimens include peri-procedural cortico steroids and antihistamines. There is no universal agreement on the degree of renal impairment precluding use of intravenous contrast. Commonly, institutions limit contrast administration to patients with serum creatinines less than 1.5 mg/dL. Certain conditions increase the risk of developing contrast nephrotoxicity. These include patients with underlying renal compromise, diabetes, dehydration, and use of certain medications such as metformin and non-steroidal anti-inflammatory drugs. With worsening renal function, renal contrast uptake and excretion becomes impaired and limits the utility of administering contrast. In those patients who develop nephrotoxicity, usually the renal impairment is non-oliguric and transient, being noted after 1–2 days and lasting 1–2 weeks.

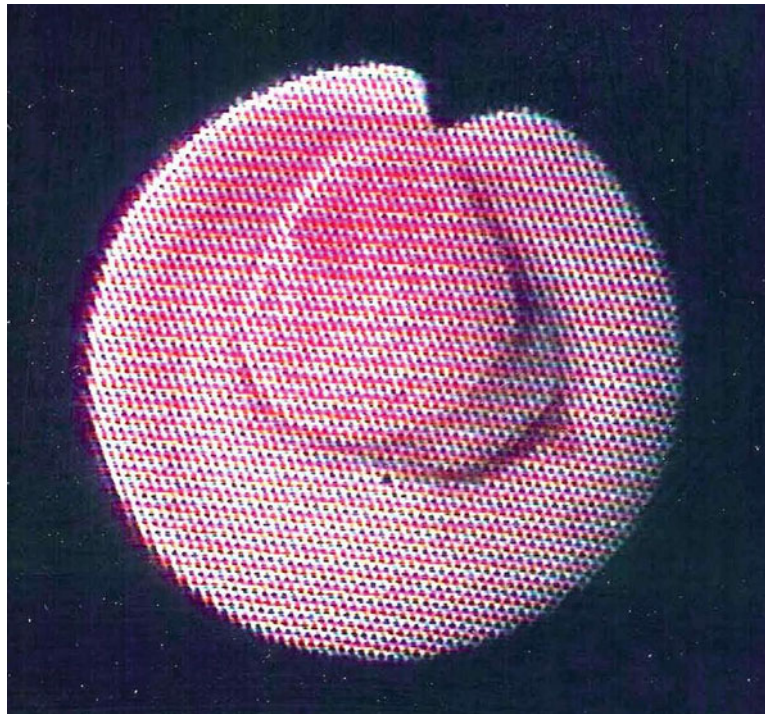

Fig. 18.1 Endoscopic image of venous malformation on renal papilla

Luminal Clots

Passage of bloods clots may be one of the most common causes of upper urinary tract obstruction other than stones. Urothelial and renal cell carcinoma commonly present with hematuria but uncommonly with acute renal colic due to the passage of blood clots. Bladder cancer is far more common than urothelial cancer involving the renal collecting system and ureter. Gross painless hematuria from bladder lesions is far more common than colic due to passage of clots from upper tract lesions. Eliciting a patient's history of tobacco usage is important to document given this being the most common risk factor associated with developing urothelial cancer. Similarly, renal cell carcinoma presents with hematuria and sometimes renal colic due to the passage of clots down the ureter. Renal angiomyolipomas are benign renal tumors also capable of presenting with significant hemorrhage and clot colic. Benign vascular lesions of the renal papillae may bleed spontaneously causing upper tract obstruction. These lesions are commonly small arterial or venous malformations found on the surface of renal papillae (Fig. 18.1).

Renal bleeding may result from use of anticoagulation medications that are above therapeutic range. This occurs most commonly on patients chronically taking Warfarin. Recent urologic instrumentation can result in upper tract bleeding following endoscopic instrumentation to treat stones, renal biopsy or partial nephrectomy for small renal tumors.

Papillary Necrosis

Papillary necrosis is an uncommon but important etiology to consider in any patient presenting with signs and symptoms of upper urinary tract obstruction. Papillary necrosis describes ischemic necrosis of the distal segments of the renal pyramids [4]. The marginal blood supply and hypertonic environment of the tip of renal papillae make this area of the kidney susceptible

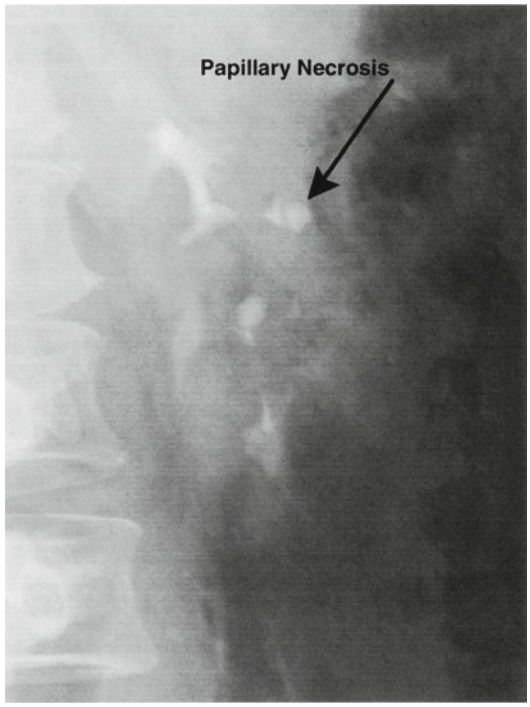

Fig. 18.2 Intravenous pyelogram demonstrating papillary necrosis

to ischemic necrosis [5]. The condition is characterized by several radiographic findings upon contrast imaging, which include contrast-filled clefts in the renal medulla, filling defects in the renal pelvis and ureter, and hydronephrosis caused by obstructing sloughed papillae (Fig. 18.2). The etiology of papillary necrosis is most often associated with analgesic abuse, diabetes mellitus, sickle cell disease, and obstructive uropathy [6–8].

Presentation

Patients with papillary necrosis typically present with symptoms of renal colic and UTI. Occasionally, fragments of papillary renal tissue may be visible on urine microscopy. Elevation of the serum creatinine may be caused by preexisting renal compromise, urinary obstruction, or dehydration caused by fever or nausea/vomiting. Historically, the diagnosis of papillary necrosis was made by IVP; the widespread use of CT imaging in the acute care setting has replaced IVP. Unlike obstructing ureteral calculi, sloughed papillae do not exhibit high Hounsfield units and may only be visible as a filling defect seen on contrast imaging. Other than visualizing renal papillary defects associated with this condition, one must consider this etiology in any high risk patient demonstrating upper tract obstruction without a visualized calculus.

Management

The acute management of patients with papillary necrosis is similar to any patient presenting with upper urinary tract obstruction. Patients with intractable symptoms of pain or nausea/vomiting, obstruction contributing to renal compromise, or signs/symptoms of upper UTI should undergo a procedure to restore renal drainage. Given that many patients with papillary necrosis typically have conditions associated with renal compromise and immunosuppression, urgent decompression is often necessary. Restoration of renal drainage can be accomplished by either cystoscopic placement of an internal stent or placement of an external nephrostomy tube. Broad-spectrum antibiotics should be given to any patient suspected of having an infection.

Fungal Bezoars

Fungal infections of the urinary tract are often nosocomial and are increasingly prevalent due to the rising number of patients with underlying risk factors. Fungi are opportunistic pathogens and typically cause UTI in debilitated and immunocompromised patients. Infections are associated with diabetes, prolonged antibiotic exposure, malignancy, and malnutrition [9]. Candida species are the most common fungi associated with UTI.

Presentation

Fungal infections are often incidentally found in chronically debilitated patients or critically ill intensive care patients with indwelling venous and urinary catheters. Presentation may be similar to that of patients with bacterial infections including fevers, irritative voiding, or symptoms of pyelonephritis. Fungal UTIs can be associated with forming "fungus balls" also known as bezoars. Fungal bezoars in the upper urinary tract are capable of causing ureteral obstruction similar to stones. The radiographic appearance of bezoars is one of a radiolucent filling defect on contrast radiography. Microscopic examination of the urine may reveal pseudohyphae which are the budding form of yeast.

Treatment

There is no universal agreement on the number of colony counts signifying infection or the need for treatment, especially in those with indwelling catheters or nephrostomy tubes. Patients with signs of systemic infection or evidence of upper tract obstruction should be treated with antifungal agents and their obstruction resolved either by nephrostomy placement or internal stenting. Historically, intravenous Amphotericin B has been the gold standard for treating patients with systemic or severe infections but is limited by significant toxicity. Newer antifungal agents have been developed with less toxicity, such as fluconazole. Direct irrigation of the upper urinary tract with dilute Amphotericin B solutions in patients with nephrostomy tubes has been described [10].

Congenital UPJ Obstruction

Congenital obstruction of the ureter is usually diagnosed and treated during infancy. Urinary tract obstruction in infants and children is most often caused by ureteropelvic junction (UPJ) obstruction but can also be caused by ureteral ectopia or a ureterocoele. Congenital UPJ obstruction is usually associated with renal units having a single ureter whereas ureteral ectopia and ureterocoeles are usually associated with ureteral duplication or renal units having two ureters. The most common cause of congenital obstruction is primary UPJ obstruction which can be caused by intrinsic ureteral developmental abnormalities, ureteral kinking from renal rotational abnormalities or compression from an accessory lower pole renal vessel.

Presentation

The widespread use of antenatal ultrasonography has resulted in the diagnosis of congenital obstruction being known prior to delivery in most infants. Infants not having antenatal ultrasonography or having normal antenatal examinations usually present with a febrile illness, failure to thrive or palpable abdominal mass. Older children present with flank/abdominal pain, symptomatic UTI, or hematuria. Symptoms often can be confused for a gastrointestinal disorder. Some patients with congenital UPJ obstruction do not present until adulthood. UPJ obstruction in adults presents as renal colic, hematuria, or UTI. Many patients may describe a history of past episodes of colic prior to diagnosis. Dietl's crisis refers to severe flank/abdominal pain and nausea/vomiting brought on by drinking fluid. Physiologically, this is explained by a rapid expansion of the kidney resulting from diuresis.

Diagnosis

The evaluation of any infant or child suspected of having renal colic or renal obstruction begins with a renal ultrasound. In such pediatric patients found to have either hydronephrosis or infection, a voiding cystourethrogram is necessary to evaluate patients for the presence of vesicoureteral reflux, the most common cause of hydronephrosis in an infant. The latter testing is not necessary in the emergency setting, however. From these studies, a diagnosis of UPJ obstruction can be made and distinguished from other less common

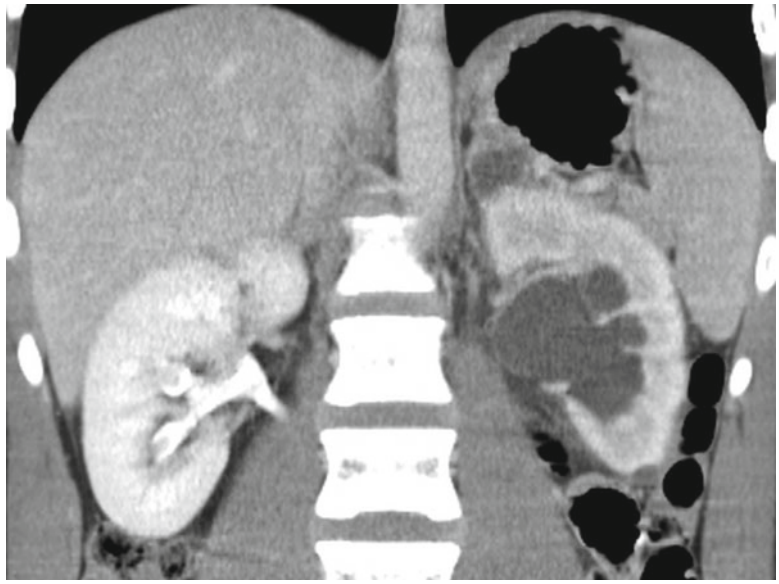

Fig. 18.3 Coronal CT image of left ureteropelvic junction obstruction. Note the absence of contrast in the dilated left calyces and renal pelvis

causes of obstruction. Diuretic renography may be beneficial to establish ipsilateral renal function and document the degree and level of ureteral obstruction. In adult patients with UPJ obstruction, the diagnosis is typically found upon CT imaging and confirmed with diuretic renal nuclear scintigraphy (Fig. 18.3).

Management

Patients with UPJ obstruction rarely present with signs or symptoms necessitating urgent management. Most commonly, patients' symptoms lead to the finding of hydronephrosis by ultrasound or CT, prompting further radiographic imaging. Nevertheless, patients presenting with intractable symptoms of renal colic, signs or symptoms of upper tract infection, or compromised renal function need to be managed by percutaneous nephrostomy or internal stent placement. A nephrostomy may be preferable in those requiring urgent intervention, to avoid inflammatory changes from internal stenting that may make subsequent ureteral reconstruction difficult.

Once the diagnosis of UPJ obstruction is established, only selected patients require immediate treatment. Partial insignificant UPJ obstruction has been described in both children and adults, who have been safely monitored without subsequent change in renal function. Absolute indications for surgical intervention include development of symptoms or infection, loss of ipsilateral renal function, and the development of renal stones.

The historical gold standard for treatment of UPJ obstruction is surgical reconstruction. Surgical principles include excision of the abnormal ureteral segment, positioning of the new UPJ in a dependent drainage position, and transposition of the UPJ posterior to any crossing vessels. Techniques implementing endoscopic incision of the UPJ were developed but provide less long-term successful outcomes compared to open reconstruction. In adult patients, laparoscopic reconstruction has become the treatment of choice to treat UPJ obstruction. Laparoscopic and robotic techniques are favored over open reconstruction due to improved cosmesis and faster convalescence. These advantages are applicable to older children and adults but open reconstruction is still most common in infants and young children.

Ureteral Strictures

Ureteral strictures can be either congenital or acquired. The majority of strictures are acquired and result from iatrogenic trauma and improper healing of the ureter. Prior to the widespread use of endourologic techniques to treat urolithiasis, strictures of the ureter most commonly occurred following ureteral injury during gynecologic and pelvic surgeries. Now endoscopic instrumentation to treat upper urinary tract stones account for the majority of ureteral strictures. Ureteroenteric strictures form at the anastomosis between the ureter and intestinal segment following urinary diversion. Less common causes of ureteral strictures include chronic irritation from stones, past radiation and rare infections such as tuberculosis or schistosomiasis [11].

Presentation

Most patients with ureteral strictures are asymptomatic, demonstrating incidental hydronephrosis on imaging for other causes, although some patients may complain of minor ipsilateral flank pain. Presenting signs include hematuria, UTI or worsening of renal function. Most strictures develop within 1–2 years of the original procedure or radiation. Ureteroenteric strictures most commonly are left-sided caused by ureteral ischemia from mobilization or passage through the sigmoid mesentery.

Diagnosis

Many ureteral strictures are asymptomatic and found on routine imaging following endoscopic instrumentation for urolithiasis or surgery for pelvic malignancy. Patients developing symptoms of flank pain, hematuria, UTI or renal compromise should undergo imaging to determine the presence of urinary obstruction. CT-IVP, which includes administration of intravenous contrast, provides the most information as to the presence and site of obstruction. In patients having previous urinary diversion for urothelial cancer, delineation of the area of obstruction is important to differentiate ureteroenteric stricture from recurrent urothelial cancer (Fig. 18.4). Patients with strictures tend to have a smooth tapered area of obstruction that develops early while patients with recurrent urothelial cancer have an area of obstruction which is irregular and occurs later in time. Patients with underlying renal compromise should be evaluated by ultrasonography. If hydronephrosis is detected, they can further be evaluated by noncontrast CT-KUB or cystoscopic instrumentation and retrograde pyelography.

Characteristics of the ureteral stricture greatly impact prognosis and treatment. Ureteral factors influencing treatment and outcome include location, degree of ischemia, and length of segment involved. In patients suspected of having poor ipsilateral renal function, renal nuclear scintigraphy is indicated. Poor renal function is considered a poor prognostic factor for endoscopic incision and nephrectomy should be considered in any patient with ipsilateral renal function less than 10–15 % of overall function.

Management

The initial management of patients with ureteral strictures is dictated by patient symptoms, presence/absence of infection, and overall renal function. The majority of patients with ureteral strictures are asymptomatic with hydronephrosis detected on imaging. In asymptomatic patients with normal renal function, contrast CT imaging is most beneficial to delineate stricture characteristics and define surrounding anatomical structures.

Ureteral strictures can be treated with chronic drainage, formal surgical reconstruction or endoscopic incision. Surgical reconstruction affords the best long-term success. Endoscopic incisions can be performed either in a retrograde or antegrade fashion. Endoscopic incision with the use of a laser or placement of a specialized cutting device placed under fluoroscopic guidance has been described. Short (1 cm or less), early, and non-ischemic strictures tend to respond most favorably to endoscopic techniques. Stricture characteristics

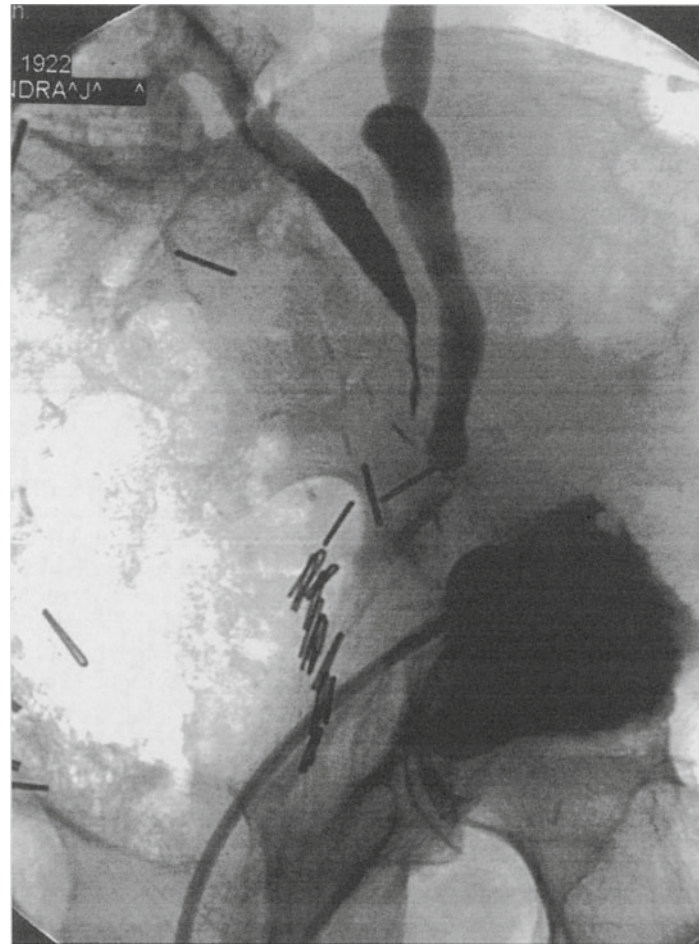

Fig. 18.4 Bilateral nephrostograms demonstrating bilateral ureteroenteric strictures. Note the smooth tapering of the dilated right ureter; the distal ureters are not visualized entering into the contrast-filled urinary diversion at the bottom of the image

associated with a poor prognosis from endoscopic incision include long length, chronic duration, and strictures associated with ischemia or radiation.

Patients with symptoms, infection, or renal compromise may require intervention to provide drainage of their kidney prior to discussion of formal treatment. This may be accomplished by placement of a percutaneous nephrostomy or internal stent. Nephrostomy placement may be preferable in patients with infection or renal compromise. Minimal instrumentation is advisable in patients with acute infection to minimize the risk of urosepsis with intervention. Contrast studies to delineate the location and length of stricture are best postponed until clearance of acute infection has been documented. In patients with a history of malignancy, cancer status and the need for future chemotherapy may impact choice of therapy. For patients with malignancy who require immediate chemotherapy, chronic drainage by stenting or nephrostomy may be preferred to optimize renal function prior to determination of definitive management.

Transitional Cell Carcinoma of the Ureter

Ureteral obstruction caused by cancer of the ureter is uncommon. Only 5 % of urothelial tumors arise in the upper urinary tract, with ureteral tumors accounting for less than 25 % [12, 13]. The majority of ureteral tumors are urothelial carcinoma and occur most frequently in patients with a past history of bladder cancer. Tobacco use is the most important risk factor for the

development of ureteral carcinoma [14]. Occupational exposure to chemicals and dyes, analgesic abuse, and cyclophosphamide have also been implicated in the development of upper urinary tract urothelial carcinoma [15].

Presentation

Gross hematuria is the most common presentation of patients with upper urinary tract urothelial carcinoma. Unlike patients with bladder cancer, patients may describe passage of vermiform clots suggestive of bleeding originating from the upper urinary tract. Patients may complain of colic related to passage of clots. Not uncommonly, patients are asymptomatic. Anorexia, weight loss, bone pain, and symptoms of advanced disease are uncommon.

Diagnosis

Patients with ureteral tumors rarely present acutely, but more commonly require referral for gross hematuria. Traditionally, patients with unexplained hematuria underwent IVP followed by cystoscopy. Increased utilization of ultrasonography and CT in the acute care setting typically reveals hydronephrosis without evidence of an obstructing stone. Ureteral tumors are identified as an irregular radiolucent filling defect on contrast imaging (Fig. 18.5).

The differential diagnosis of a radiolucent ureteral filling defect includes radiolucent stone, blood clot, sloughed renal papilla, ureteral kink, or vascular impression [16]. Uncommon causes include benign fibroepithelial polyp, endometriosis, amyloidosis, fungal bezoar, or metastases. Further evaluation with ureteroscopic inspection and biopsy is diagnostic. Voided urine cytology alone is not sensitive enough to diagnose most tumors [17].

Management

Nephroureterectomy with excision of a small cuff of bladder is the traditional treatment for patients with upper urinary tract urothelial carcinoma. Laparoscopic nephroureterectomy is feasible and is the standard of care at most academic centers. Endoscopic resection is an option for patients who are a high surgical risk or have compromised renal function, solitary kidneys, or bilateral disease. Prognosis is dependent more on grade and stage of disease than method of treatment [18, 19].

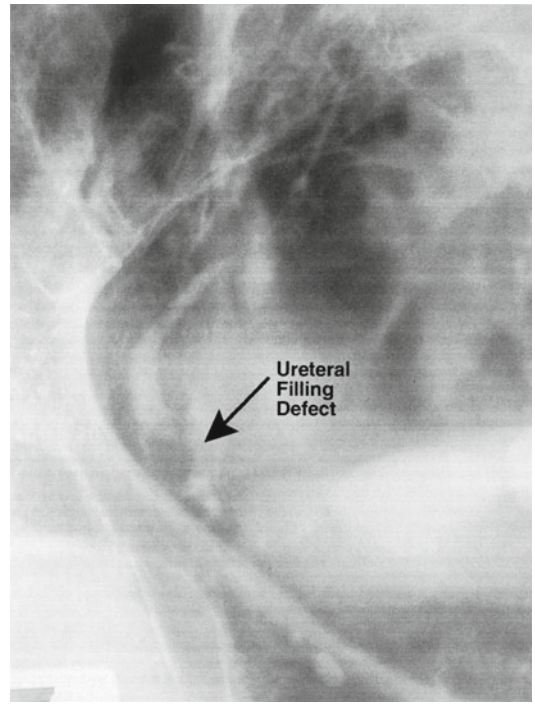

Fig. 18.5 Filling defect in distal right ureter representing urothelial carcinoma

Retroperitoneal Fibrosis

Retroperitoneal fibrosis (RF) is an uncommon but important cause of upper urinary tract obstruction. It is characterized by a fibroinflammatory mass typically encasing the aorta and iliac vessels. Fibrosis typically involves retroperitoneal structures at the level of the fourth and fifth lumbar vertebra but can extend as cephalad as the renal hila. The hallmark of the disease is entrapment of the ureters, causing hydronephrosis and progressive azotemia.

There are many known etiological factors associated with formation of RF; however, most cases are idiopathic. Known causes of RF and malignancy must be excluded prior to making a diagnosis of idiopathic RF. Idiopathic RF is most commonly found in men between the ages of 40–60 years [20]. Historically, the use of analgesics, most commonly methylsergide, was associated with RF. Retroperitoneal fibrosis may also represent an autoimmune disease given its association with other autoimmune diseases such as rheumatoid arthritis and systemic lupus erythmatosis and its response to treatment with oral steroids in some patients. RF must be distinguished from retroperitoneal lymphadenopathy caused by malignancy, the most common being lymphoma. Other than malignancy, radiation, infection, aneurysmal dilation of the aorta and trauma have all been associated with RF.

Presentation

The presentation of patients with RF is typically vague and nonspecific related to azotemia from ureteral obstruction. Most commonly, patients present with vague noncolicky back or abdominal pain [21]. Patients may also complain of malaise, anorexia, and weight loss occurring over several months. Rarely, patients present with signs of UTI or anuria. Constriction of the aorta causing lower extremity ischemia and inferior vena caval constriction causing lower extremity edema can rarely occur. Palpable abdominal mass, lower extremity edema, and hypertension are the most common clinical findings with advanced cases [21]. Laboratory investigation typically demonstrates azotemia and varying degrees of anemia, depending on the severity of renal insufficiency. An erythrocyte sedimentation rate (ESR) should be ordered in any patient thought to have RF. Historically, patients with an elevated ESR have been considered to have more of an acute inflammatory component to their RF and likely to be more responsive to treatment with oral steroids. A recent study of 37 patients treated with corticosteroids however found ESR and C-reactive protein to be poor predictors of therapeutic response [22].

Diagnosis

The diagnosis of RF is best made by CT. RF appears as a soft-tissue mass enveloping the aorta and vena cava (Fig. 18.6). Ureteral involvement and hydronephrosis can be unilateral (20 %) or bilateral (68 %) [21]. RF has the same attenuation as muscle and variable enhancement on intravenous contrast administration. Retroperitoneal fibrosis may be difficult to distinguish from retroperitoneal neoplasms. In contrast to RF which typically causes medial displacement of the ureters, neoplasms laterally displace ureters [23]. Percutaneous, laparoscopic, or open biopsy may be required to exclude malignancy prior to empiric treatment for RF. Because most patients have significant renal impairment at the time of presentation, intravenous contrast administration is often not feasible. Patients with renal insufficiency should be evaluated by either ultrasonography or noncontrast CT. Retroperitoneal fibrosis by sonography appears as a smooth-margined hypoechoic mass centered over the sacral promontory.

Management

The initial management of a patient with RF involves restoration of renal drainage and correction of electrolyte abnormalities. Renal drainage can be achieved by either placement of internal stents or external nephrostomies. Once patients have been stabilized, tissue sampling to differentiate RF from cancer may be necessary.

Definitive therapy for RF is bilateral ureterolysis followed by intraperitonealization and/or omental wrapping of the ureters to prevent future constriction. Treatment of both ureters even in the setting of unilateral obstruction is recommended. Relief of ureteral obstruction is successful in approximately 90 % of cases undergoing surgical ureterolysis [24]. Laparoscopic ureterolysis has been reported, but requires longer operating times and expertise in laparoscopy [25]. The use of steroids alone for the treatment of RF is controversial, especially in those without a definitive exclusion of malignancy. Steroids have been useful as an adjunct to ureterolysis and

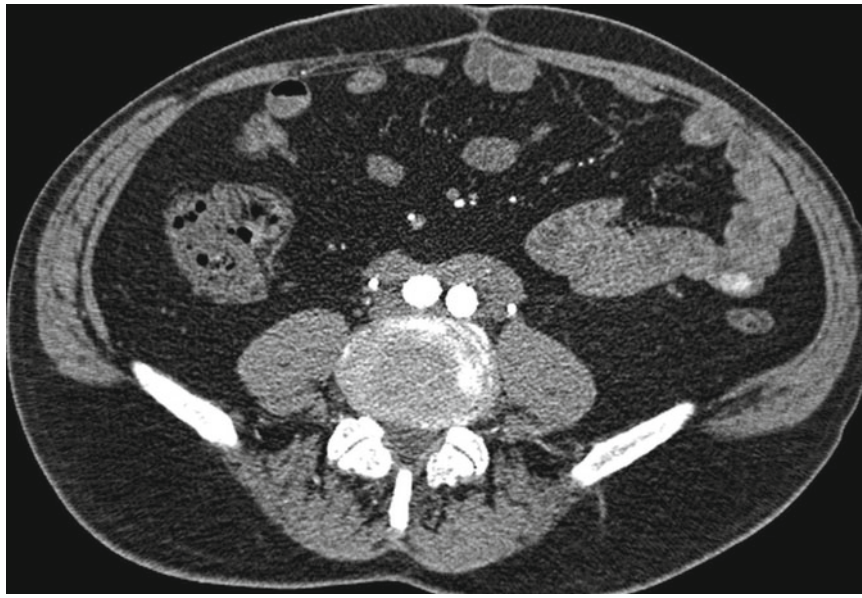

Fig. 18.6 Computed tomography of pelvis demonstrating retroperitoneal fibrosis surrounding the common iliac vessels and ureters. The ureters appear as contrast filled structures at the lateral edge of the fibrotic mass

in elderly or debilitated patients who are not ideal surgical candidates. Patients presenting with an elevated ESR, reflecting active inflammation, are most responsive to steroid therapy [26]. Other immunosuppressive agents such as tamoxifen and cyclosporin have been used to treat patients with RF [27, 28].

Conclusions

Upper urinary tract obstruction due to etiologies other than urinary stones is uncommon. The principles of initial evaluation and management are similar and center on determining the need for urgent intervention to drain the obstructed kidney. Symptoms of colic refractory to medical management, signs of complicating infection and obstruction contributing to renal insufficiency are indications to place either an internal ureteral stent or external nephrostomy. CT imaging affords rapid evaluation of the urinary tract and surrounding organs but physicians need to be aware of the potential deleterious effects of excessive radiation exposure. Definitive diagnosis and treatment often requires contrast imaging to delineate ureteral anatomy prior to definitive management.

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Urgent and Emergent Management of Acute Urinary Retention

19

Cheryl Shih and Claire C. Yang

Introduction

Acute urinary retention (AUR) is the sudden, typically painful, inability to volitionally empty the bladder. Physiologically, AUR is the inability of the detrusor muscle to produce and sustain a reflex contraction with adequate intravesical pressure to completely empty the bladder. The clinical condition of AUR can be objectively measured as a volume of post-void residual (PVR), but there is no universally accepted numerical value or relative increase in the volume of PVR to define AUR. Historically, AUR has been classified as either precipitated or spontaneous. Trigger factors, such as surgery, urinary tract infection, or intake of medications with sympathomimetic or anticholinergic effects, can induce precipitated AUR [1]. However, in many cases, AUR occurs in the absence of an identifiable triggering event and is referred to as spontaneous AUR, which may simply be related to the natural history of benign prostatic hyperplasia (BPH). Untreated AUR may lead to complications related to urinary stasis (urinary infections and stones), bladder over-distention (urgency and pain), and elevated intravesical pressure (hydronephrosis and acute renal insufficiency or failure).

Epidemiology

Population-based studies have reported various estimates on the overall incidence of AUR in men, ranging from 2.2 to 6.8 events per 1,000 men yearly [2]. In men, the risk of AUR is related to BPH and increases exponentially with age, approximately doubling with every 10-year increase, from an annual incidence of 1.31/1,000 men in the fifth and sixth decades of life, to 16.80/1,000 men in the eighth and ninth decades of life [3]. In women, AUR is uncommon, and epidemiological estimates are difficult due to the variable and poorly understood underlying conditions that cause AUR in women. Although rare, AUR in children is frequently associated with neurological abnormalities, behavioral voiding dysfunction, and constipation [4]. Other causes of urinary retention are not well studied within large populations.

Anatomy and Neuroanatomy

The bladder is a smooth muscle organ that serves as a reservoir for urine. Its function is to store urine until the reservoir is full and to release urine when socially appropriate to do so. Urine storage

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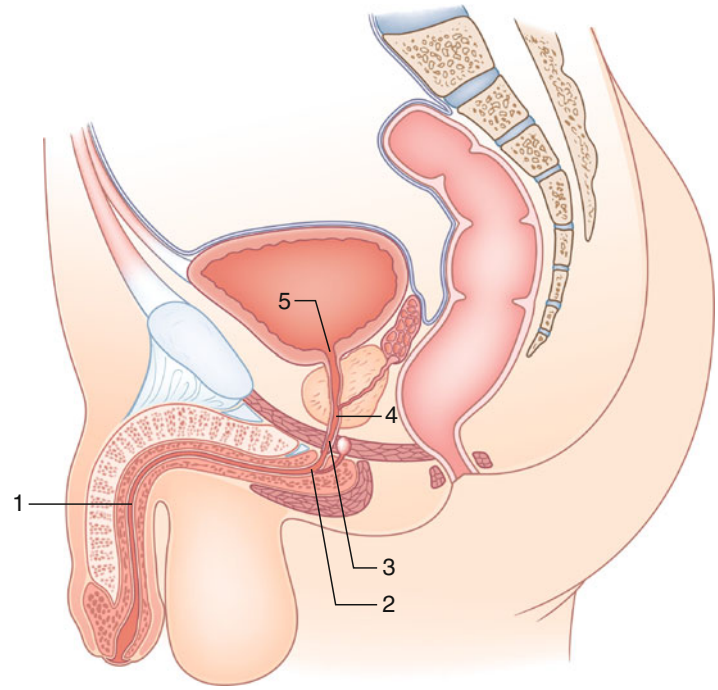

Fig. 19.1 The male urethra is approximately 16 cm in length and is divided into (1) penile urethra, (2) bulbar urethra, (3) membranous urethra, (4) prostatic urethra, and (5) bladder neck

is achieved through the closure of the bladder neck (also called the internal sphincter) and external striated sphincter, with quiescence of the detrusor muscle. Voiding is achieved with contraction of the detrusor and coordinated opening of the sphincters.

The primary anatomic differences in the lower urinary tract between men and women are the presence of a prostate enveloping the proximal portion of the male urethra, and the longer length of the male urethra (see Figs. 19.1 and 19.2). The male adult urethra is approximately 16 cm in length, divided into the bladder neck, prostatic urethra, membranous urethra, bulbar urethra, and penile urethra. The female adult urethra is approximately 4 cm in length.

Coordinated bladder and sphincter function largely depends on intact somatic and autonomic innervation. Parasympathetic nerves arise at the sacral spinal cord and course through pelvic nerve and pelvic plexus, joining with the thoracolumbar sympathetic efferents that follow a course through the hypogastric plexus. Together, they provide autonomic innervation to the bladder. Parasympathetic efferents mediate bladder contraction; sympathetic nerves inhibit the detrusor and maintain tone in the bladder neck. The somatic pudendal nerves carry motor innervation from Onuf's nucleus in the sacral spinal cord to innervate the external urethral sphincter. Afferent fibers of these nerves transmit information from the bladder and external urethral sphincter to the lumbosacral spinal cord and central nervous system. Both the somatic and autonomic nerves form reflex loops involving central nervous system pathways, to initiate and maintain the bladder storage and voiding functions. Any disruption along the neural pathways results in abnormal bladder function.

Etiology

The etiological factors of AUR are related to increased bladder outlet resistance, insufficient bladder contractility, or both.

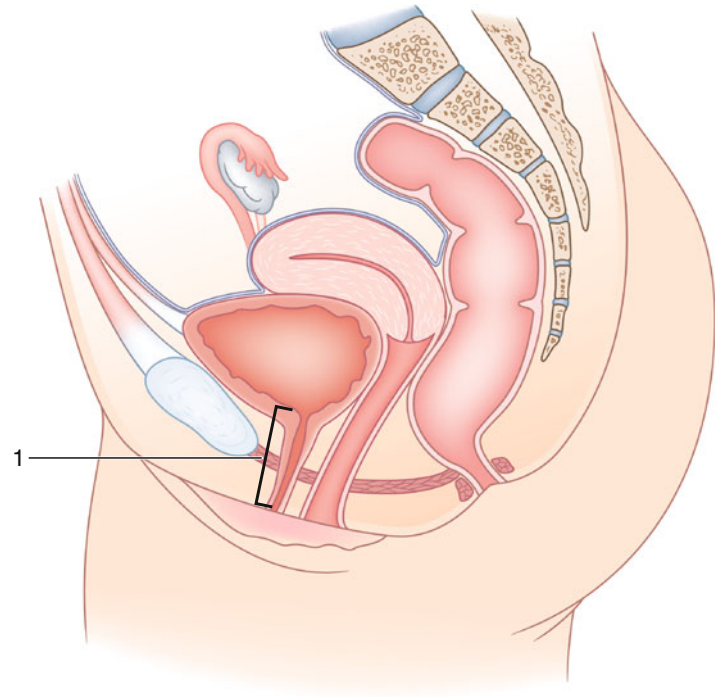

Fig. 19.2 The female urethra (1) is approximately 4 cm in length

Bladder Outlet Obstruction

Bladder outlet obstruction is most commonly seen in men, although it can be encountered in women and children as well. Table 19.1 lists the causes of bladder outlet obstruction in males, and Table 19.2 lists the causes in females.

Intravesical foreign bodies, such as bladder stones and blood clots from urinary tract bleeding, can form a mechanical obstruction causing urinary retention. Urethral strictures and urethral disruption from trauma can also present with urinary retention. In children, congenital lesions of the proximal urethra, such as posterior urethral valves in boys, can cause bladder outlet obstruction.

Prostatic urethral obstruction, most commonly by benign prostate hyperplasia (BPH), is a frequent cause of bladder outlet obstruction in older men. The prostate, which encircles the proximal male urethra, grows into the urethral lumen and bladder neck, creating a barrier to efficient urine evacuation. The clinical manifestation of BPH and AUR was defined in a meta-analysis, whereby the rate of progression to AUR in the placebo arms of randomized controlled trials of medical therapy for BPH ranged from 0.4 to 6.6 % [5]. Several studies have demonstrated an association between increased serum PSA and larger gland size with the risk of AUR [6–8]. In the placebo arm of one large randomized study looking at men with BPH, both a prostate volume of 31 mL or greater and a PSA 1.6 ng/mL or greater in placebo-treated subjects were predictive of an increased risk of AUR [7]. Prostatic infectious and inflammatory conditions, such as acute bacterial prostatitis and prostatic abscesses, can cause AUR through urethral edema or possibly disruption of normal voiding reflexes.

Lesions of the spinal cord may cause functional obstruction, presenting as bladder neck dyssynergia or detrusor sphincter dyssynergia. Dyssynergia, or loss of coordination between the contracting detrusor and opening of the sphincter, is seen in multiple sclerosis, spinal cord injury, and other myelopathic diseases. It can also occur in neurologically intact children and adults, and is then known as dysfunctional voiding.

Iatrogenic causes of bladder outlet obstruction include antihistamine and α (alpha)-adrenergic

Table 19.1 Male bladder outlet obstruction

Bladder neck
Bladder neck dyssynergia
Bladder neck contracture
Clot retention
Bladder stone
Drugs that increase bladder neck tone
Prostatic urethra
Benign prostate hyperplasia
Prostate cancer
Acute prostatitis, prostatic abscess
Posterior urethral valves
Membranous urethra
Detrusor external sphincter dyssynergia
Dysfunctional voiding
Penile urethra
Meatal stenosis
Paraphimosis
Anywhere in the urethra
Urethral calculus
Urethritis
Stricture
Urethral tumor or polyp

Table 19.2 Obstructive lesions of the female lower urinary tract

Bladder neck
Clot retention
Bladder stone
Drugs that increase bladder neck tone
Intraurethral lesions
Tumor
Meatal stenosis or urethral stricture
Urethral diverticulum
Periurethral abscess
Urethral prolapse
Extrinsic urethral factors
Pelvic mass/fibroids
Iatrogenic causes (pubovaginal sling or urethral suspension surgery)
Pelvic organ prolapse (cystocele, rectocele, uterine prolapse)
Female circumcision/genital mutilation
Functional causes
Detrusor external sphincter dyssynergia
Primary bladder neck dysfunction
Dysfunctional voiding

agonist medications, such as ephedrine, pseudoephedrine, phenylephrine, or phenylpropanolamine, which may increase bladder outlet/urethral resistance. Postoperative AUR in men occurs with some regularity, without regard to the type of surgery performed. In women, urethral suspension and sling procedures for stress urinary incontinence can cause postoperative AUR. Transient obstruction is usually attributable to urethral edema, but prolonged obstruction can occur when excessive tension from the sling or suspension procedure compresses the urethra too tightly. Hong et al. reported AUR occurring in 32 of 343 patients (8.6 %) who underwent tension-free transvaginal tape (TVT) placement [9].

Impaired Detrusor Contractility

Impaired detrusor contractility (Table 19.3) may result either from neurogenic causes related to disorders of either afferent or efferent neural pathways, or from a problem of the bladder muscle itself (myogenic). Acute cerebrovascular accident is one of the transient causes of AUR. The pathophysiology of detrusor areflexia in "cerebral shock" is unclear.

Acute spinal cord injury causes flaccid paralysis of the nerves and muscles below the level of the injured segment. Flaccid paralysis of the detrusor muscle during "spinal shock" results in AUR. In patients with lesions above the sacral spinal cord, detrusor contractions return after a period of paralysis lasting from a few days up to several months, whereas the retention persists in lesions involving S2 to S4 spinal cord segments.

Urinary retention caused by impaired detrusor contractility occurs in patients with peripheral polyneuropathies such as diabetic polyneuropathy or chronic alcoholism. In diabetes mellitus, several other factors may also contribute to impaired detrusor contractility, such as polyuria, loss of bladder sensation, functional and structural changes in the detrusor, and chronic over-distension that results in secondary detrusor damage. There are typically signs and symptoms of bladder dysfunction long before the development of AUR. Persons with known lumbosacral disk

Table 19.3 Causes of impaired detrusor contractility

Neurogenic
Supraspinal level
Cerebrovascular accident
Brain tumor
Parkinsonism
Multiple sclerosis
Spinal level
Spinal shock following spinal injury
Lesions affecting sacral S2–4 spinal cord or nerve roots (disk disease, spinal stenosis)
Sacral spinal cord tumors
Congenital neurospinal defects (myelomeningocele, lipomeningocele, sacral agenesis)
Multiple sclerosis, transverse myelitis, other myelopathies
Guillain-Barré syndrome
Anogenital herpes
Multi-system atrophy (Shy Drager syndrome)
Polio
Infraspinal level
Peripheral mono- or polyneuropathies
Diabetes mellitus
Chronic alcoholism
Pernicious anemia
Heavy metal poisoning (lead, mercury)
Peripheral nerve injury (traumatic or surgical), including nerve root impingement
Myogenic
Prolonged, severe obstruction
Aging
Tuberculosis
Radiation cystitis
Other
Infrequent voiding
Psychogenic retention
Postoperative urinary retention
Constipation
Chronic pelvic pain syndrome
Drugs that impair detrusor contractility

disease or injury may also be at increased risk for impaired detrusor contractility, due to compromise of nerve roots mediating bladder function.

Pelvic trauma and abdominopelvic surgery can cause peripheral nerve damage, leading to AUR. Viral infections (e.g., herpes zoster) can involve the pelvic nerves and cause detrusor muscle paralysis, but this usually resolves as the infection clears. Intravesical botulinum toxin injection is increasingly being used to treat overactive bladder, and a potential adverse effect is urinary retention requiring catheterization that resolves as the medication effects wear off [10].

In children, chronic constipation or fecal impaction can lead to incomplete bladder emptying and treatment of the bowel disorder resolves the associated urinary retention. The pathophysiology may be related to the effects of chronic rectal distension on voiding reflexes.

Chronic bladder outlet obstruction has also been known to cause impaired bladder contractility, referred to as the "decompensated bladder." Relief of the obstruction may not reverse the damage done to the contractility of the bladder. Psychogenic urinary retention may be encountered in patients who experience intermittent episodes of AUR associated with emotional distress.

Clinical Findings

History

In an emergency setting, a detailed history is often deferred until after a procedure to relieve the AUR can be performed. A brief history should be taken for relevant urologic conditions to avoid exacerbating problems such as urethral trauma or stricture with overzealous urethral catheterization.

For a detailed history, information should be obtained regarding the duration of urinary retention, any previous history of retention, and the identification of precipitating factors such as fluid overload and alcohol intake. Patients often have a recent history of lower urinary tract symptoms, such as increased urinary frequency and urgency, dysuria, decreased force and caliber of urinary stream, terminal dribbling, urinary hesitancy, and other symptoms indicative of worsening bladder outlet obstruction. Any history of hematuria is important, since blood clots can cause bladder outlet obstruction. A history of hematuria would also raise suspicions of possible malignancy. In patients with abnormal bladder sensation, decreased urine output, flank or abdominal pain, or a sense of fullness in the pelvic region may be the only symptoms of AUR.

Past medical history should focus on systemic neurological disease, diabetes mellitus, genitourinary or pelvic malignancy, or recent abdominopelvic surgical procedures. Sexually transmitted diseases such as gonorrhea are relevant since urethritis is associated with urethral stricture disease.

Many medications, including sympathomimetics, anticholinergics, antihistamines, antidepressant drugs, narcotics, antipsychotics, and sedatives, may precipitate AUR. Acute retention also commonly occurs after general or regional anesthesia.

Physical Examination

Examination of the abdomen may reveal a suprapubic mass or fullness, particularly if the patient is thin. Percussion of a distended bladder produces a high-pitched, dull sound. Surgical scars of the abdominal wall should be documented and taken into consideration when suprapubic cystostomy is indicated, since prior lower abdominal surgery will increase the risk of bowel perforation when attempting intravesical access.

The urethral meatus should be carefully examined for the presence of meatal stenosis, polyps, caruncles, and other lesions. Phimosis may be present in men of all ages, but this is not usually the primary cause of retention. Inspection may also reveal genital herpetic lesions.

Digital rectal examination is important for diagnosing an enlarged, indurated, or nodular prostate in older men. An exquisitely tender prostate, in the setting of other symptoms of a febrile urinary infection, may indicate acute prostatitis or prostatic abscess, the latter of which will require surgical drainage. Anal sphincter tone and a bulbocavernosus reflex should be checked to assess the neurologic integrity of the sacral spinal nerves in both men and women.

In females, a bimanual examination is useful to detect uterine, cervical, or other gynecologic masses. Rarely, genital or pelvic masses may only be detected after bladder emptying; thus it might be necessary to perform a rectal or bimanual examination following catheterization.

After bladder decompression is achieved with catheterization, the urine volume should be measured and documented. The catheter is usually left in place.

Laboratory Evaluation

Laboratory tests are not useful for the clinical diagnosis of AUR, but labs drawn at the time of the initial evaluation may be helpful for further patient management. Urinalysis and urine culture is useful in evaluating potential urinary infection. Serum urea nitrogen and creatinine levels are necessary to assess the impact on renal function. Baseline serum electrolytes are pertinent to the ongoing management of post-obstructive diuresis (see section "Immediate Post-drainage Management").

Imaging

If the history and physical examination are inconclusive, pelvic ultrasonography is the easiest and fastest imaging modality for detecting a distended bladder. It can also detect the presence of foreign body, calculus, clot, mass, or an enlarged prostate. Renal ultrasonography may be necessary to reveal complications of AUR, such as hydronephrosis, particularly in the setting of renal insufficiency. A retrograde urethrogram may be indicated in a trauma evaluation if there is concern of urethral disruption, usually related to straddle injury or pelvic fracture (see Chap. 6). A kidney, ureter, bladder (KUB) plain film can detect spinal anomalies, such as spina bifida. Urinary retention can manifest as a faintly opaque bladder shadow in the pelvis.

Treatment of AUR

An algorithm for AUR management is offered in Table 19.4. The treatment objectives of AUR are to establish urinary drainage, identify a cause of AUR to prevent future episodes, and to minimize harm to the urethra.

Table 19.4 AUR treatment algorithm

History, physical exam, imaging (if needed)
Urethral catheterization or suprapubic cystostomy
Labs: urinalysis and gram stain, urine culture, BUN, creatinine and electrolytes
If BUN, creatinine are elevated, observe for postobstructive diuresis
If bacteriuria present, begin antibiotics
Diagnose underlying cause of AUR, if possible: impaired contractility, bladder outlet obstruction, or both?

Urethral Catheterization

Typically, the first maneuver to establish urinary drainage is to place a Foley catheter per urethra. Compared to suprapubic cystostomy, urethral catheterization is generally more expeditious and less morbid.

In women, urethral instrumentation is seldom difficult. However, in the setting of morbid obesity or female hypospadias, when the urethral meatus is within the vaginal canal, the meatus may be hard to visualize. An uncommon situation resulting in difficult female urethral catheterization is the patient who has undergone extensive female circumcision or genital mutilation. In these women, the introitus is reconstructed or scarred so that the urethral meatus is not visible. The adult female urethra is approximately 4 cm long and located in the midine. Thus, even the hypospadiac meatus has to be located along the anterior vaginal wall, within 4 cm of its usual position. Placing a gloved fingertip of the nondominant hand deep on the anterior vaginal wall while sliding a 14 or 16F Coudé tip catheter (with the tip up) along the finger should result in the catheter entering the meatus. In women with significant uterine prolapse, the uterus may first need to be reduced to visualize the urethral orifice.

With children, it is crucial to avoid urethral injury. If a few simple attempts to catheterize a child's urethra are unsuccessful, then extensive instrumentation should be avoided, and one should proceed to suprapubic cystotomy.

Difficult Foley catheter placements usually occur in men, since BPH can distort the male urethra, exaggerating the angle of the proximal urethra and making negotiation with a catheter challenging. Generous urethral lubrication is critical. ("Float it in on a river of lube," attributed to Dr. William H. Boyce, Bowman Gray School of Medicine, Winston-Salem, NC.) Sterile, water-soluble lubricant can be loaded into a 10 cc syringe and injected directly into the urethra. According to one systematic review, studies looking at lidocaine jelly vs. placebo (plain lubricating jelly) for the relief of pain during flexible cystoscopy in male patients have produced conflicting results, but the suggestion is that lidocaine jelly may reduce moderate to severe pain during urethral catheterization [11]. Data are conflicting regarding the most effective instillation amount, rate, and dwell time, so the use of lidocaine jelly with urethral catheterization is mostly left to individual preference [12]. It is common to use between 10 and 20 cc of 2 % lidocaine jelly and to clamp the penis for a 10 min dwell time to allow for effect.

The first attempts at adult male urethral catheterization can be with a 16 or 18F Foley catheter. Smaller caliber catheters may be necessary to traverse narrow strictures, but in general, the problem is far more commonly an enlarged prostate, and the small caliber catheter may not be stiff enough to negotiate a resistant passage.

The penile shaft should be grasped and gently stretched upward, perpendicular to the body. The catheter should be advanced through the urethral meatus and penile urethra until it reaches the membranous urethra (usually signaled by increased resistance). The penis is then brought down toward the scrotum, still on stretch, until it is parallel to the body, so as to lever the catheter tip through the membranous urethra. If this is not successful, a similar sized Coudé tip catheter can be attempted. The Coudé tip catheter has a curved tip pointing anteriorly to traverse the angle of the male bulbar urethra. The raised bleb on the connector end of the Coudé catheter points in the same direction as the curved tip to help the operator keep the catheter oriented properly.

Advanced Techniques for Urinary Drainage in AUR

If the above techniques are not successful, a urology consultation is necessary, as the following maneuvers should only be performed by trained practitioners. There are increased risks of urethral perforation, rectal perforation, and other complications in inexperienced hands.

Negotiating the Difficult Urethra

A Seldinger technique can be attempted by passing a guide wire or 5F open-ended catheter into the bladder and advancing a Councill catheter over it. A Councill catheter is identical to a Foley catheter, except that it has a small hole in the tip through which a wire can pass.

Urethral stricture dilation can be accomplished either un-guided or over a wire with van Buren or Goodwin urethral sounds respectively. The urethra should be dilated to two or three sizes larger than the caliber of the catheter. As with all urethral instrumentation, the tip of the sounds should hug the anterior wall of the urethra to avoid perforation in the posterior wall of the bulbar urethra.

Stylet-guided catheter placement with a Mandarin guide can also be attempted. The stylet has a gentle curve at the end, mimicking the curve of the bulbar urethra.

Historically, filiforms and followers have commonly been used. Filiforms are long, slender nylon rods used to "snake" through urethral obstructions into the bladder. Once the filiform is passed into the bladder, a series of graduated followers, which are hollow tubes advanced over the shank of the filiform, are used to dilate the obstruction.

Finally, with the increasing availability of flexible cystoscopy, direct visualization can be invaluable in negotiating a difficult urethra. Once the obstruction is visualized, a guide wire can be passed through the urethral lumen into the bladder. Then, Goodwin sounds and a Councill catheter can be used to dilate the urethra and establish drainage.

Suprapubic Cystostomy

Punch Cystostomy

If all reasonable attempts to establish urethral drainage have failed, or an injury contraindicates urethral catheterization, and the patient's condition requires immediate urinary drainage, a "punch," or percutaneous, cystotomy tube can be placed. This procedure is generally reserved for those patients who are not on anticoagulation therapy, do not have known bladder malignancy, and have not had lower abdominal or pelvic surgery via an abdominal incision. Previous surgery increases the risk of intestinal adhesion to the lower abdominal wall through which the cystotomy tube is placed, thus increasing the risk of intestinal perforation. Punch cystotomies can be performed with ultrasound guidance to minimize the risk of injuring the bowel.

Open Suprapubic Tube

If the patient is not a candidate for punch cystotomy, or in the setting of significant pelvic trauma, an "open" suprapubic tube can be placed in the operating room, often in conjunction with other operative procedures. The bladder should be inspected for complete integrity, and perforations can be simultaneously repaired. In some situations, a suprapubic tube placed next to hardware stabilizing the pelvic ring may not be desirable. In this case, a large Foley urethral catheter with a closed-system pelvic suction drainage may be the best option.

Immediate Post-drainage Management

Once urinary drainage is achieved, a urine specimen should be sent for urinalysis and culture. In the presence of infected urine, antibiotics should be started, particularly if the catheterization was traumatic.

The patient should be monitored for post-obstructive diuresis. Approximately 0.5–52 % of

patients experience post-obstructive diuresis, depending on how this condition is defined in the literature [13]. Proposed mechanisms include osmotic diuresis due to the accumulation of urea, hormonal alterations, dysfunction of proximal or distal nephrons, and altered tubular permeability. Post-obstructive diuresis is typically self-limiting (24–48 h), but can be life-threatening if copious salt and water loss causes derangements in serum electrolyte levels and hydration. Persistent urine output of 150–200 mL/h should prompt close monitoring of serum electrolytes and fluid replacement. Patients should be given free access to oral fluids. If necessary, intravenous fluid replacement in the form of 0.45 % saline can be administered at approximately half the rate of urine output.

Bladder hemorrhage from damaged mucosal vessels may also occur following decompression. Keeping the bladder free of clots to maintain catheter patency is essential and may require continuous bladder irrigation if the degree of hematuria is severe.

In select cases when the patient is an outpatient, reasonably healthy, and reliable, clean intermittent catheterization can be initiated instead of Foley catheterization to avoid complications of indwelling catheterization.

Long-Term Management

AUR is frequently transient, and once the inciting event is resolved (discontinuation of medication, treatment of infection, resection of obstructing prostate), spontaneous voiding is possible. A trial without catheter (TWOC) can be performed using the "fill-and-pull" method, by which the bladder is filled with sterile saline or water via the indwelling catheter to the patient's capacity (≤450 cc), and then the catheter is removed. The patient is then asked to void, and the amount voided is measured. If there is more than 200 cc PVR, then the patient may be at risk for recurrent urinary retention.

Failure of a TWOC requires re-catheterization, with all the attendant disadvantages related to catheter-associated complications (pain, hematuria, infection, stricture, and false urethral passage). Any intervention that would increase the chance of a successful TWOC would be very beneficial. Alpha-adrenergic antagonists have been shown to reduce bladder neck and prostatic tone via blockade of alpha 1-adrenoceptors [14]. There is evidence that alpha-blockers can improve the chances of a successful TWOC in AUR due to BPH. A Cochrane Database meta-analysis showed a statistically significant benefit of alpha-blockers, usually given for 24–72 h prior to catheter removal, compared to placebo (RR 1.39, 95 % CI 1.18–1.64) [15].

If the cause of the AUR is not reversible, long-term management of urinary retention can be via indwelling urethral or suprapubic catheter or with clean intermittent catheterization. The patient's overall health, physical and cognitive capacity, and social support will determine which type of management is most appropriate.

Summary

AUR is a true urologic emergency. The etiologies are related to bladder outlet obstruction, impaired detrusor contractility, or both. Bladder drainage is necessary to relieve pain, and avoid complications of infection and irreversible renal damage. The diagnosis of AUR is typically straightforward. Treatment by urethral catheterization is preferable, but placement may be difficult, requiring suprapubic cystotomy. Immediate post-drainage sequelae include post-obstructive diuresis and hematuria.

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Part V

Iatrogenic Complications

Vesicovaginal Fistula and Ureteral Injury During Pelvic Surgery

20

Christopher S. Elliott and Craig Comiter

Introduction

Because of the proximity of the bladder and ureters to the uterus, iatrogenic injuries are a well-described complication of gynecologic surgery. If unrecognized, complications such as vesicovaginal fistula (VVF) and ureterovaginal fistula (UVF) may occur. VVF ranks as the second most common genitourinary tract injury, with the second highest cause of malpractice claims [1, 2]. Given the morbidity suffered by the patient and the medicolegal implications realized by the surgeon [3], the avoidance, recognition, and subsequent treatment of these complications are an important issue. This chapter focuses on iatrogenic causes of VVF and ureteral injuries, strategies to prevent and recognize them, and management of postoperative complications.

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Vesicovaginal Fistula

Definition and Etiology

A VVF is an anomalous communication between the bladder and the vagina. In developing countries, the most common cause is unrelieved obstructed labor [4–7]. In West Africa, prolonged labor results in VVF at a rate of 1–3 per 1,000 deliveries [4]. In more developed countries in which women have better access to more modern obstetric care, obstetric fistulas are much less common. In such areas, fistula formation most typically results from iatrogenic injury during pelvic surgery [8–11].

In fact, 90 % of VVFs in North America result from gynecologic surgery [12]. Abdominal and vaginal hysterectomies are the most common causative factors, accounting for 75 % of all VVFs [11, 13, 14]. The risk of fistula formation following hysterectomy is approximately 0.1 % [8–11]. Other iatrogenic causes include injury during laparoscopic pelvic surgery, antiincontinence procedures, gastrointestinal pelvic surgery, and pelvic radiation [15, 16]. Noniatrogenic fistulas may result from locally advanced pelvic malignancy [14, 17], foreign bodies [18–20] or in rare cases, infection due to tuberculosis [21], aspergillosis [22], or schistosomiasis [23].

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Pathogenesis

During obstructed labor, there is prolonged pressure exerted on tissues between the vaginal canal and the pubic bone by the infant's head lodged against the pubic bone for an extended period; ischemic injury to these tissues (i.e. bladder, urethra, and occasionally the rectum) results, causing significant tissue loss [24]. Risk factors for obstructed labor have been identified as women who are primiparous, younger age at conception, short in stature as compared to their peers and carrying a male fetus [25].

The foremost mechanisms of VVF formation following vaginal or abdominal hysterectomy are (1) unrecognized cystotomy or insufficiently repaired cystotomy, resulting in urinoma formation with subsequent fistulization to the vaginal cuff and (2) vaginal cuff sutures that inadvertently incorporate the posterior bladder, resulting in necrosis and fistula formation [26]. VVF formation after radiation results from progressive obliterative endarteritis, and may occur many years after treatment [24, 27].

Prevention

The prevention of the majority of obstetric fistula in the developing world is dependent on improvements in the healthcare infrastructure of those regions. To this end, care of the patient both during her pregnancy and during her delivery is necessary with the availability of prompt access to emergency obstetric services should labor become complicated. While improved obstetric care is recognized as an important step in lowering the rate of urogenital fistula in the developing world, this goal is far from being met at this time [28].

Prevention of urogenital fistula in the developing world also plays a large role in the overall wellbeing of the patient. Unfortunately, a large proportion of these patients end up ostracized from their communities, with up to 70 % facing divorce (which often leads to a life of poverty), and many are even banned from eating with their families [29, 30]. In several studies, rates of psychiatric disturbance in affected patients reach up to 97 %, with over half of these patients having suicidal thoughts [29, 31].

The most common factors that increase the risk of posthysterectomy VVF include previous pelvic radiation, prior uterine surgery, and a history of endometriosis. In addition, previous cervical conization [24], distorted anatomy secondary to fibroids or adnexal mass [32], and steroid use [33] have been affiliated with increased risk of VVF. Therefore, elective hysterectomy in a high-risk patient should be performed by an experienced surgeon with the availability of urological assistance if necessary [34].

The bladder's proximity to the cervix and anterior vaginal wall renders it susceptible to injury during hysterectomy. Prevention of inadvertent bladder injury is best accomplished by adherence to basic principles of surgery, namely, a thorough knowledge of surgical anatomy, as well as adequate surgical exposure and hemostasis. During hysterectomy, the bladder is most likely to be injured supratrigonally, at the level of the vaginal cuff. Sharp dissection, rather than the use of cautery or swabs, should be used to dissect the bladder off the uterus [11, 35]. Moreover, the bladder should be continuously decompressed during pelvic surgery with an indwelling catheter. If bleeding occurs, specific ligation of the bleeding site is preferred to excessive cautery. Prior to ligation of the uterosacral ligaments, adequate mobilization of the inferior and lateral aspects of the bladder is essential, and the ligaments should be taken close to the uterus to avoid injury to the bladder [36]. When extensive pelvic and perivesical fibrosis are encountered, *intentional* anterior cystotomy may be performed to prevent *accidental injury* to the bladder base [37]. Also, consideration of supracervical hysterectomy should be given when applicable as lower rates of urogenital fistula have been observed in those with subtotal hysterectomies as compared to total hysterectomy. The likely mechanism of such an effect is that bladder dissection off the cervix and upper vagina, where most injuries occur, is avoided [38].

Evidence suggests that cystoscopy at the end of hysterectomy cases is much more sensitive in identifying injuries to the bladder than strict

Table 20.1 Tissue interposition during vesicovaginal fistula repair

Abdominal approach
Greater omentum
Peritoneal reflection
Appendix epiploica of colon
Myofacial rectus flap
Posterior bladder wall advancement flap
Vaginal approach
Labial fat graft (Martius flap)
Peritoneum
Sartorius muscle
Gluteus muscle
Gracilis muscle

visual inspection (96 % vs. 38 %, respectively) [39]. If injury is suspected, the bladder should be filled with fluid to localize any site of leakage. Repair of the injury should not be attempted until tissues are adequately mobilized [40]. Urological consultation is recommended, and the cystotomy should be closed with self-absorbing suture (SAS) in multiple layers. If the closure is tenuous, interposition of adjacent well-vascularized tissue between the cystotomy repair and the vagina is recommended. The most commonly used interposition grafts are greater omentum, peritoneum, or labial fat grafts (Table 20.1). The development of a VVF after bladder injury repair has been identified to be much more likely in those injuries that extend into the trigone or bladder neck [41]. These injuries should also be considered for interposition grafts at the time of repair. The bladder should be drained via indwelling catheter for 2–3 week postoperatively, with catheter removal only after cystographic confirmation of complete healing. The majority of bladder injuries if managed appropriately in this setting will heal without formation of VVF (~97 %) [42].

Presentation

Bladder injuries not recognized during surgery may present immediately postoperatively or up to 3 week later. Radiation-induced fistulas may present up to 20 year after radiation [24, 43]. Patients typically present with continuous daytime and nighttime leakage per vagina [44]. Depending on the size of the fistula, varying amounts of urine may be voided vs. leaked per vagina. Patients may initially present with postoperative abdominal/pelvic pain and ileus secondary to urinoma formation [26] prior to frank fistulization of the urinoma to the vagina.

Diagnosis

The differential diagnosis of clear fluid per vagina includes urine, lymph, peritoneal fluid, fallopian tube exudates, and vaginal discharge [45]. A high fluid creatinine level confirms the diagnosis of urinary fistula. Identifying the origin of leakage—ureter, bladder, or proximal urethra—is the most important first step [12].

Vaginal examination with a speculum is mandatory for identifying the fistulous site, most commonly at the apex of the vaginal vault. With a large fistula, a bladder catheter may be visible or palpable per vagina. If the exam is unrevealing and suspicion remains high, methylene blue or indigo carmine can be instilled into the bladder via urethral catheter, and leakage may be observed per vagina.

Alternatively, the diagnosis may be confirmed by static cystography with lateral views (Fig. 20.1). Case reports using computed tomography to identify fistulas have also been reported but plain film remains the imaging standard. Cystoscopy is indicated to identify the relation of the fistulous opening to the ureteral orifices, to document free urinary outflow from each ureter, and to assess bladder capacity and rule out concomitant foreign body. With a patient who has a history of genitourinary carcinoma, biopsy is necessary to rule out recurrent malignancy [44].

Concomitant UVF must be excluded because the incidence of UVF exceeds 10 % in patients with a VVF [3, 13, 37]. Cystoscopy is usually performed as a primary examination with the presence of ureteral jets used to document patency. Intravenous urography, commonly performed with CT-IVP, and/or retrograde ureteropyelography are useful for identifying hydronephrosis,

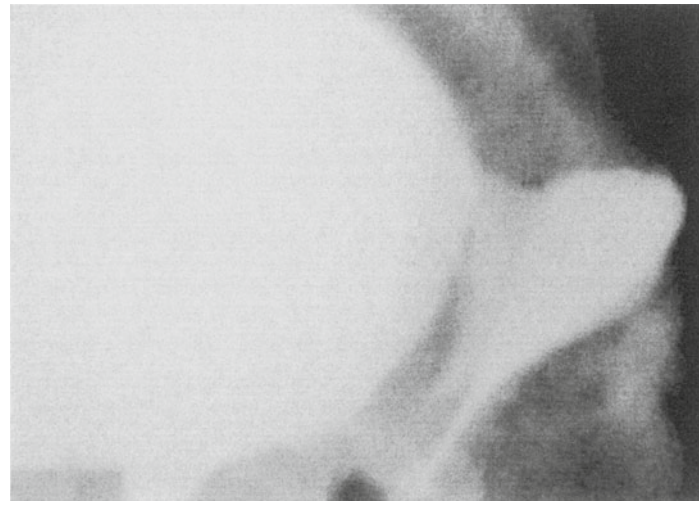

Fig. 20.1 Lateral cystogram demonstrating vesicovaginal fistula

ureteral obstruction, and fistula formation. If the diagnosis remains uncertain, the bladder may be catheterized and filled with blue dye while the patient is given oral pyridium. The vagina can be packed with gauze, and the patient asked to ambulate with a plugged urethral catheter. Blue staining confirms VVF; orange staining confirms UVF [46].

Concomitant Stress Incontinence

In addition to being a primary risk factor for VVF development, prior hysterectomy has also been identified as a risk factor for the development of stress urinary incontinence (SUI) [47]. Because of the continuous leakage per vagina however, the patient may not notice stress incontinence. In support of this, one investigation suggested that stress incontinence perceived as new onset following VVF repair may have been present before the repair was undertaken [48]. Any woman with a prior history of urinary incontinence must be adequately evaluated prior to fistula repair and warrants evaluation with multichannel videourodynamics if indicated. While a cough stress test after bladder filling may not be possible due to leakage out the fistulous tract at low bladder volumes, a positive "empty" cough stress test generally suggests a Valsalva leak point pressure less than 60 cm water [49]. Another finding suggestive of stress incontinence on videourodynamics is an open bladder neck during the filling phase, as this is typically not observed in continent patients [50]. Bladder neck funneling during provocative maneuvers is also more common in those with more severe SUI [51]. Lastly, maximal urethral closure pressure during urethral pressure profilometry is significantly less in women with SUI as compared to those without and can help to aid in diagnosis [52]. Repair of anatomic abnormalities contributing to stress incontinence may be performed concomitantly with fistula surgery (via abdominal or vaginal route) and may avoid the need for a further surgical procedure. Most important, incontinence surgery has not been demonstrated to increase fistula recurrence [43]. The use of synthetic sling material is not contraindicated unless the fistula repair involves the urethra.

In those patients with obstetric fistula, only one quarter is usually "dry" after successful closure of the VVF [53]. In a series of such patients complaining of incontinence who underwent subsequent urodynamic studies, over half were found to have SUI alone, with another third having mixed incontinence [54]. Risk factors for the development of incontinence in this population are injuries that include the urethra, are larger than 6 cm in size, and are associated with small bladder capacity (<50 cc) or in those needing more than one repair to close their VVF [55].

Management

Although most cases of VVF will ultimately require surgery for definitive cure, conservative management should be offered for small fistulas uncomplicated by ischemia, radiation, or malignancy. Continuous urethral catheter drainage plus oral antimuscarinics and antibiotics have been associated with a 2–10 % closure rate [3, 11, 33, 56, 57]. However, once the fistulous tract becomes epithelialized (usually 4–6 week), catheter drainage is unlikely to aid fistula closure [3]. A trial of deepithelialization has been advocated for mature small fistulas (1–3 mm) using silver nitrate, mechanical curettage [58], electrocautery [59], or laser therapy. Both Nd-YAG and holmium laser welding were successful for sealing small fistulas (up to 4 mm in size) in a recent series of 7 VVF patients with a 100 % success rate at a minimum 2-month follow-up [60]. Fibrin glue has also been described in the treatment of VVF, though to date no series with more than 1 case exist [61–65]. The use of a synthetic substance for fistula closure, cyanoacrylic glue, was recently reported on in 4 patients with VVF. In this series, 2 of 4 patients had cure at 5 months or more of follow-up. In both patients that failed, the fistula was greater than 1 cm in size, again suggesting that the use of these materials should be reserved for smaller fistulae [66].

For large VVFs and for the majority of smaller ones that fail conservative management, surgery is required for definitive repair. The routine use of preoperative urethral catheterization is controversial. Although bladder drainage may reduce skin excoriation and patient discomfort, catheterization exacerbates bladder sensitivity, intravesical inflammation, and the risk of urinary infection. It is generally recommended that any indwelling catheter be removed at least 1 week prior to surgery, and that the urine should be sterilized with broad-spectrum antibiotics at least 24 h prior to surgery. Preoperative estrogen replacement is recommended in postmenopausal women [67], and any vaginal yeast infection should be treated with an oral or vaginal antifungal agent.

Timing of Surgery

If a bladder injury or ureteral injury is recognized during pelvic surgery, urological consultation is recommended at this critical time, and immediate repair is warranted. The immediate repair of such bladder and ureteral injuries is covered in Chap. 21.

Although surgery had traditionally been deferred for 3–6 month following the injury to allow maximum resolution of the inflammation and edema, it is now commonplace to proceed to earlier and even immediate repair of iatrogenic VVF. A short waiting period is still recommended for a fistula related to obstetrical trauma to allow the ischemic tissue to declare itself fully. Similarly, with radiation-induced VVF, the surgeon should wait until the size of the fistula has stabilized, as verified by serial vaginal and cystoscopic examination. For radiation-induced fistulas associated with obliterative endarteritis, a waiting period of at least 12 months is recommended [24, 27].

Early surgical intervention for uncomplicated VVF caused by iatrogenic injury is now recommended because many series document excellent success rates with early fistula repair [8, 68–73]. One small series demonstrated excellent outcomes (92 % success) with surgical intervention as soon as 2–4 weeks after the initial injury presentation [74]. A larger series of 80 consecutive patients, comparing repair in patients with VVF at 3 months or earlier ($n=40$) as compared to those repaired at later than 3 months ($n=40$), showed no difference in outcomes (88 % success in each group) [75]. In addition, early repair avoids the discomfort associated with urinary leakage (odor, skin excoriation, urinary tract infection) as well as the adverse psychological and medicolegal impact of prolonged urinary leakage [32].

Surgical Technique

The principles of surgical repair are as follows: The fistula tract must be adequately exposed, and the fistula repair should be tension-free, watertight, multilayered with nonoverlapping suture lines, and should remain uninfected (Table 20.2). Whether the approach is vaginal, abdominal, or

Table 20.2 Principles of surgical repair for vesicovaginal fistula

Preoperative
Timing of repair
Vaginal vs. abdominal approach
Health of tissues
Estrogenization
Steroid use
Radiation
Planning of concomitant procedures
Stress incontinence surgery
Prolapse surgery
Augmentation cystoplasty
Ureteral surgery
Intraoperative
Good exposure of fistulous site
Wide mobilization of tissues
Tension-free approximation of tissue
Watertight closure
Multilayer repair with nonoverlapping suture lines
Interposition flaps
Postoperative
Avoidance of infection
Maximal and continuous bladder drainage
Adequate estrogenization
Prevention of bladder spasms

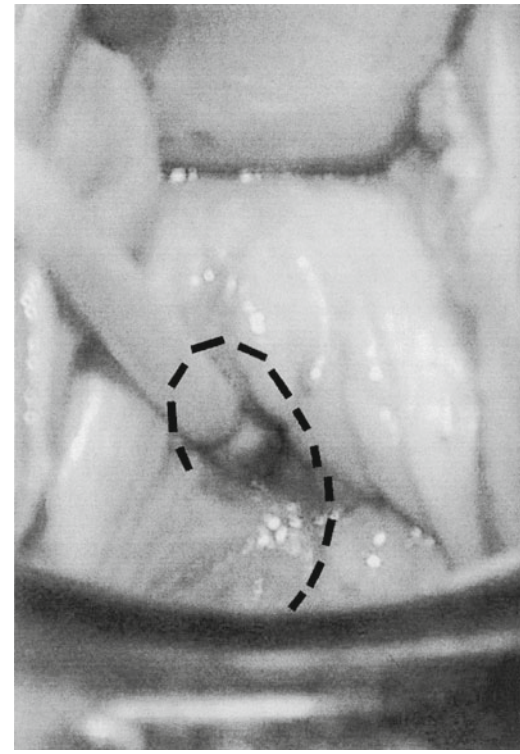

Fig. 20.2 Fistulous tract is dilated, and 8F Foley catheter is inserted. Inverted J incision aids with raising vaginal wall flaps anteriorly, posteriorly, and laterally

a combination of both routes, the initial attempt at repair has the highest success rate [4, 24]. The best approach should depend on the patient's anatomy, location of the fistula, and reconstructive considerations; these decisions must be individualized for each case. Compared to abdominal surgery, the transvaginal approach is associated with significantly decreased morbidity and length of hospitalization [76].

Vaginal Approach

Most VVFs are amenable to transvaginal repair. A vaginal operation is far less burdensome for patients than is an abdominal approach [14, 40, 77, 78]. Contraindications to the vaginal approach include severe vaginal stenosis and an inability to tolerate the dorsal lithotomy position (e.g., because of muscular contraction/spasticity). If the fistula encroaches on the ureteral orifices, transurethral placement of ureteral stents is indicated. Placement of both a urethral and suprapubic catheter can decrease the chance of postoperative catheter obstruction. Additionally, if the patient experiences bladder spasms refractory to antimuscarinics, the urethral Foley may be discontinued, thereby removing the catheter balloon from irritating the trigone, leaving the suprapubic tube for bladder drainage.

For access to the vagina, the patient is positioned in dorsal lithotomy. The fistulous tract should be dilated with lacrimal duct probes and pediatric urethral sounds until an 8F Foley catheter, which may be used for traction, can be inserted into the bladder. The vaginal wall surrounding the fistula is instilled with saline via a hypodermic needle to aid with subsequent dissection. The fistula is circumscribed sharply, and the incision is extended as an inverted J, with the long arm of the J ending at the vaginal apex (Fig. 20.2).

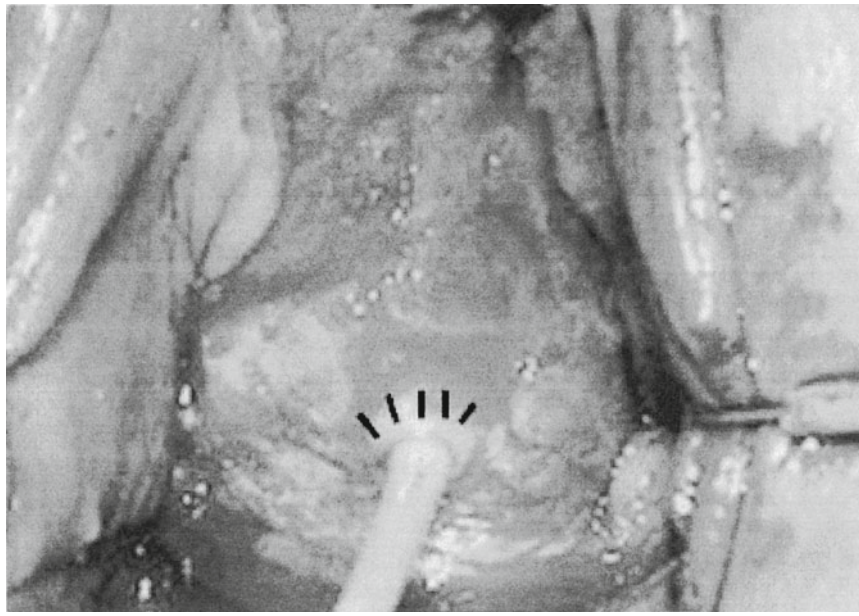

Fig. 20.3 Catheter is removed, and fistula is closed with 3-0 self-absorbing suture

Vaginal wall flaps (2–4 cm wide) are created anteriorly, posteriorly, and laterally. The perivesical fascia is exposed, and the circumscribed fistulous tract is left intact in contrast to general surgery principles in which it is entirely excised. Excision of the tract may unnecessarily enlarge the fistula and might increase the risk of bleeding. This approach is supported by a recent randomized trial showing no increase in successful closure rates whether or not the fistula edges were trimmed at the time of surgery. In fact, in those patients who failed, the resultant fistula was larger than the previous fistula in a majority of cases in which the fistula was trimmed as compared to the non-trimmed group [79]. Furthermore, the fibrous ring of the fistula can help improve the strength of the repair by providing a strong anchor for suture placement [44]. Prior to closure, the intrafistula catheter is removed, allowing for transverse closure of the tract with interrupted 2-0 SAS (Fig. 20.3).

A tension-free second closure layer is placed perpendicular to the first layer in an imbricating fashion, incorporating the perivesical fascia and detrusor muscle 5 mm from the previous closure. Should the surgeon be unable to close this layer tension-free despite adequate dissection, thought should be given to performing a one layer repair only. Alternatively an application of fibrin glue over the repair, which shows similar efficacy to local tissue flaps in a randomized trial of complicated VVF, can be performed [80]. Integrity of the closure is tested by filling the bladder via the urethral catheter. The distal vaginal flap is excised, and the proximal flap is advanced anteriorly at least 2–3 cm beyond the fistula repair. This third layer is closed with a running 2-0 SAS, covering the site of repair with healthy vaginal tissue, while avoiding overlapping suture lines (Fig. 20.4).

Abdominal Approach

All VVFs can be approached transabdominally. Abdominal repair is recommended, however, when the fistulous opening cannot be adequately exposed vaginally; simultaneous bladder augmentation is planned; or simultaneous ureteral surgery/ureteroneocystotomy is planned.

The patient is placed in the supine position with the legs slightly abducted to allow access to the vagina. Through a Pfannenstiel or lower abdominal midline incision, an intraperitoneal or

Fig. 20.4 Vaginal wall flap is advanced anteriorly 3 cm beyond the fistula repair

extraperitoneal approach to the bladder may be utilized. Packing the vagina is often helpful to temporarily seal the fistula so that the bladder can be filled through a urethral catheter.

Extraperitoneal Approach

The bladder dome is elevated, and dissection is carried posterior to the bladder and anterior to the vagina, down toward the fistulous tract. After the fistula is identified, a small opening is made sharply in the tract, and the bladder wall can be dissected off the tract. The vaginal opening and the bladder opening are each closed in two layers using 2-0 slowly absorbable suture (SAS) [40]. Perivesical or extraperitoneal fibrofatty tissue may be interposed between the two layers. Alternatively, a peritoneotomy may be used to harvest an omental flap, or the peritoneal reflection itself may be interposed between the bladder and vaginal closures. A transvesical extraperitoneal approach has also been described in which the fistulous tract is excised transvesically [81, 82].

Intraperitoneal Approach

The bladder is approached transperitoneally, and the bladder is bisected down to the fistula. The bladder and vagina are widely mobilized from each other, and the fistula is excised. The bladder and vagina are each closed in two layers using 2-0 SAS [83, 84]. When operating transperitoneally, harvesting an omental graft is more straightforward. If omentum does not easily reach the site of repair, a rotational flap based on the right gastroepiploic artery may be mobilized and secured between the bladder and vaginal closure with 3-0 SAS [85]. A suprapubic tube is placed in addition to the urethral catheter to allow maximal bladder drainage. A Penrose drain should be placed and brought out through a separate stab wound.

Laparoscopic Approach

A laparoscopic approach to VVF was first described by Nezhat et al. in 1994 [86]. Since that time, the use of robotic assistance to perform the case has also been described [87]. The repair of supratrigonal fistula is described in these reports and those that have followed. In brief, the patient is placed in the lithotomy position and ureteral catheters are placed bilaterally. A separate ureteral catheter is then placed through the fistula for identification purposes. A Foley catheter is introduced into the bladder and is placed on traction to prevent loss of pneumoperitoneum. The vaginal introitus is also occluded with Vaseline gauze for the same purpose. The patient is then placed in Trendelenburg to facilitate moving the bowel out of the pelvis and laparoscopic trocars are placed after pneumoperitoneum is established. The dissection and repair is then carried out in a similar fashion to the open abdominal approach. Advocates of the laparoscopic repair suggest that the pneumoperitoneum facilitates dissection of tissue planes, the magnification offered by the video camera can improve visualization of the tissue and that patient morbidity and hospital stay are decreased as compared to open surgery [86, 87].

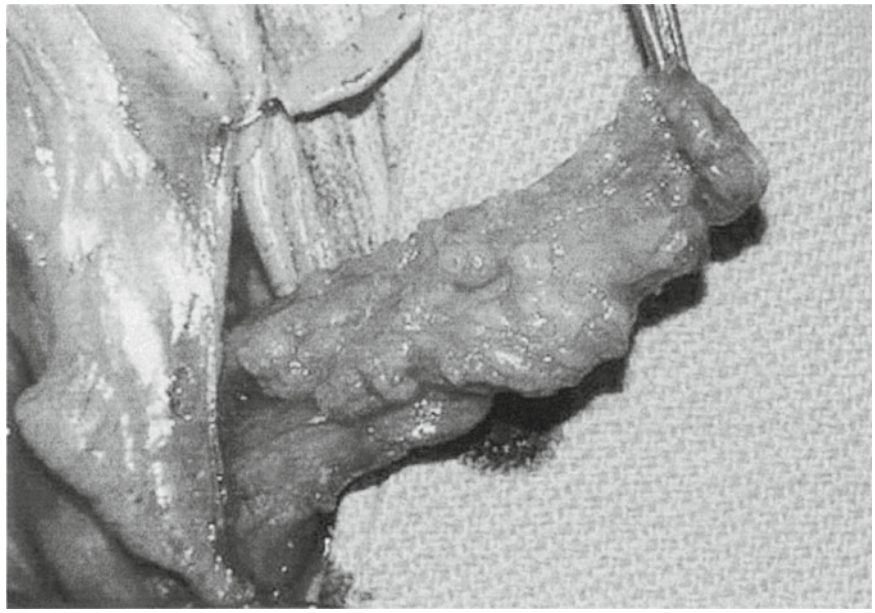

Fig. 20.5 Vascularized labial fat pad with blood supply based inferiorly on the inferior labial artery

Interposition Grafts

In cases of fistulas that are recurrent, radiation-induced, high in the vaginal vault or associated with poor tissue quality, the interposition of another source of healthy tissue is recommended (Table 20.2) [15]. In addition to the same basic principles of achieving a watertight, tension-free, uninfected repair, realizing a reliable closure often involves the need for interposing a well-vascularized tissue flap. When operating transabdominally, omental fat interposition is usually straightforward, and if increased mobility is necessary, the flap should be based on the right gastroepiploic artery [85, 88]. Alternatively, the peritoneal reflection of the cul-de-sac may be interposed between the bladder and vagina to help prevent refistulization [76]. Other choices of vascularized tissue include the appendix epiploica of the colon [33], a myofascial rectus flap [89], or an advancement flap derived from the posterosuperior bladder wall [90].

When approaching the recurrent fistula transvaginally, the most popular Martius flap derives from the labial fat pad, which can be tunneled under the labia minora to the site of repair (Fig. 20.5) [91, 92]. We prefer to use a peritoneal flap, which obviates the need for extravaginal harvesting. This technique was first described by Raz et al. [76] and involves dissecting the posterior vaginal wall flap posteriorly toward the cul-de-sac. The preperitoneal fat and peritoneum are sharply mobilized caudally. The peritoneal flap can then be advanced over the repair and secured with interrupted 3-0 SAS (Fig. 20.6).

Other reconstructive techniques have been described using sartorius, gluteus, rectus, and gracilis muscle [93–98]. These muscular and myocutaneous flaps are recommended for large radiation or ischemic fistulas [24, 93].

The use of a Martius flap interposition graft in a primary repair is not recommended based on a series of over 440 VVF repairs in which its use conferred no increase in the successful closure as compared to those repairs without a labial fat graft [99]. In contrast to this evidence suggesting no need for an interposition graft in primary fistula closures approached vaginally, evidence does support the advantage of an interposition graft when the VVF is approached abdominally. In two series where omental interposition was studied, the fistula cure rates were substantially

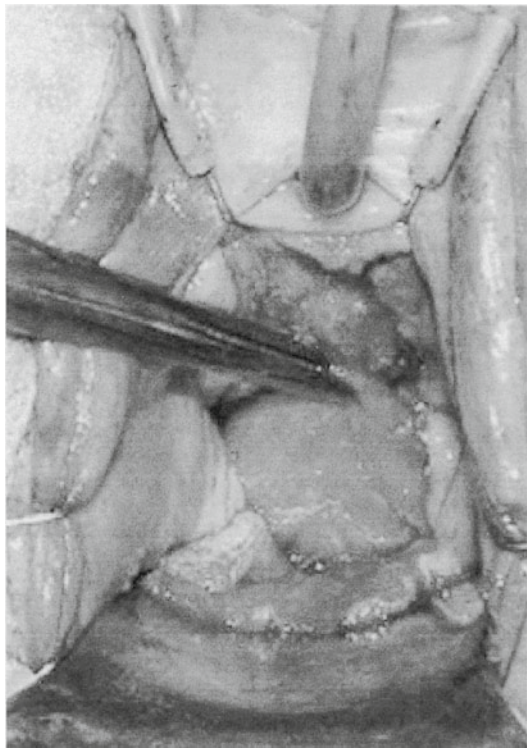

Fig. 20.6 Preperitoneal fat and peritoneum are mobilized in a caudal direction and sutured into position over the initial two-layer repair

higher in those that received an interposition graft (100 % and 93 %) as compared to those without (67 % and 35 %) [100, 101].

Postoperative Care

The vagina should be packed with an antibiotic-impregnated gauze for several hours to reduce the likelihood of vaginal wall hematoma formation. Maximal bladder drainage is recommended. In cases of simple fistula the use of a larger caliber urethral catheter alone can be undertaken or the surgeon can choose to place both a urethral and suprapubic tube. Urethral and suprapubic catheters should remain on gravity drainage until the urine is clear of any blood. The urethral catheter may be removed after the urine clears if it poses a threat of mucosal irritation at the site of repair (bladder neck or trigonal fistula) and a suprapubic catheter is in place. Extended antibiotic use after an initial 24 h of dosing in the immediate perioperative period is not necessary as evidenced by a recent large randomized control trial [102]. We do however recommend a single dose of antibiotic administration at the time of catheter removal in order to sterilize the urine after a period of colonization with the catheter in place. Bladder spasms should be treated with oral or rectal antimuscarinics because bladder overactivity has been postulated to compromise healing of the repair [103]. Oral or topical estrogen has been demonstrated to promote healing [93, 104]. To date, no study has been able to determine the exact time needed for bladder decompression with a catheter to promote optimal healing. One non-randomized study suggests no difference in recurrence rates between those catheterized for 10 days vs. 12 days vs. 14 days [105].

Cystography should be performed at 2–3 weeks postoperatively, prior to catheter removal, to document complete healing of the fistula, with discontinuation of antimuscarinics at least 24 h prior to voiding trial. If the fistula is healed and the patient voids to completion following the removal of the urethral catheter, the suprapubic tube, if in place, should be removed. If persistent fistula is noted during cystography, catheter drainage is recommended for an additional time period. Persistent leakage at 6 week requires repeat operative repair. Following successful repair, patients should avoid vaginal intercourse for 3 months.

Success Rates

Although success rates vary in the literature, approximately 85–90 % of VVFs caused by gynecologic iatrogenic surgical injury are repaired successfully at the first attempt [8, 10, 13, 69, 71, 80, 106–109]. At our institution, success rates in excess of 80 % have been achieved in repair of recurrent VVF. Other centers of excellence report similar results [40, 76]. Similar success rates are seen in patients with obstetrical fistula [99, 110]. Success rates for

radiation-induced fistulas are lower, ranging from 40 to 80 % [27, 72, 88, 93]. In the largest series on radiation induced VVF to date ($n = 216$), success rates of primary, secondary, and tertiary procedures were 48 %, 40 %, and 50 %, respectively [27]. While these success rates are lower, they do suggest that previous failure in a radiated field does not preclude further surgical treatment.

Complications

Early complications of VVF repair include vaginal bleeding, bladder spasms, and urinary or vaginal infection [44]. Intraoperative bleeding should be controlled with suture ligation, minimizing electrocautery. Postoperative bleeding is usually controlled by vaginal packing and bed rest. Bladder spasms can be treated with cholinolytics, and vaginal or urinary infections may be managed with appropriate oral antibiotics.

Late complications include unrecognized ureteral injury, vaginal stenosis, vaginal foreshortening, and fistula recurrence [44]. Vaginal shortening or stenosis usually results from excessive resection of vaginal tissue during posterior flap advancement and is more common in those with larger fistulae [4]. Delayed recognition of a ureteral injury is best managed initially by percutaneous nephrostomy, followed by definitive surgical repair after the inflammation has subsided. Cystoscopic approaches are contraindicated because distention of the bladder may lead to VVF recurrence. Recurrent fistula mandates reoperation, which is typically delayed for several months to allow the inflammation to subside. Interposition of vascularized tissue is always recommended for repair of recurrent VVF.

Complications after obstetric fistula repair are similar to those mentioned above. In addition, only 20 % of women are able to achieve pregnancy after repair of VVF, though this is likely a consequence of their previous pelvic trauma from obstructed labor rather than the repair itself. In those that are able to achieve a pregnancy following successful VVF repair, a cesarean section is preferred over vaginal delivery [111, 112].

Ureterovaginal Fistula

Definition and Etiology

A UVF may be defined as an abnormal communication involving the ureter and the vagina. This condition arises from an ectopic ureteral insertion into the vagina. It is rarely congenital, and more commonly is acquired, usually from a transmural injury to the ureter during pelvic surgery. An obstruction of the distal ureter leads to continued extravasation of urine and failure of the ureteral defect to heal. The most common cause of UVF is gynecologic surgery, most commonly after total abdominal hysterectomy for either benign or malignant disease [113]. Fistulas may also occur after prolonged or difficult delivery secondary to the pressure effect of the fetus on the distal ureter, resulting in necrosis [114].

The ureter is vulnerable during pelvic surgery because it lies close to the rectum and female reproductive organs within the pelvis. With laparoscopic pelvic surgery becoming more common, inadvertent electrocautery of the distal ureter, especially in laparoscopic hysterectomy, during ligation of the uterine artery is reported [115]. The ureter is also vulnerable to devascularization, as part of the distal blood supply originates from the uterine artery. Thus a ureter with insufficient collateral blood supply may be vulnerable to ischemic injury following routine uterine artery ligation during hysterectomy [116]. The ureteral blood supply may also be vulnerable during laparoscopic surgery, when the cardinal ligament is dissected and then divided below the uterine vessels [117]. Ureteral injury reportedly occurs in 0.5–1 % of all pelvic surgeries [118] and in 1.4–2 % of patients undergoing radical hysterectomy [119, 120]. In those in whom a concomitant VVF is present UVF exceeds 10 % [3, 13, 37].

UVFs occur when a ureteral leak persists, and the urine makes its way to the vaginal cuff. This adverse outcome of ureteral injury with its associated incontinence negatively affects the quality of life for the patient and causes anxiety on the part of the surgeon [121, 122]. Any unexplained

abdominal or flank pain or costovertebral angle tenderness, especially if fever is present, should alert the surgeon to the possibility of a ureteral injury. Often, there are no symptoms of ureteral injury or obstruction before urinary incontinence occurs. The usual UVF presentation is one of a sudden onset of urinary leakage from the vagina 1–4 week postoperatively [121, 122]. In addition to the constant incontinence, the patient voids normally because the contralateral ureter provides normal filling of the bladder.

Prevention

Prevention of unrecognized ureteral injuries is the first step in the management of this problem. A recent study suggests that relying on direct visual identification of a ureteral defect is insufficient at the time of surgery (7 % accuracy), while cystoscopic examination for ureteral efflux is vastly superior (100 % accurate) [39]. When using this technique, an intravenous injection of indigo carmine is given just prior to cystoscopy. Ureteral patency is then established cystoscopically via the visualization of contrast passing through the ureteral orfices bilaterally. Failure to achieve flow can be either due to prerenal causes (rectified by a bolus of intravenous fluid) or due to potential injury. Passage of a ureteral stent with concomitant retrograde pyelogram can serve for further diagnosis should poor or absent ureteral flow ensue and can prompt definitive repair if needed. Cystoscopic examination also has the added advantage of identifying an incidental cystotomy.

Assessment and Investigation

Several diagnostic studies have been utilized for the diagnosis of a ureteral injury in the postoperative period. Cystoscopy may reveal an absence of ureteral jets on one side and can additionally be used to screen for the presence of a bladder injury. In a female with vaginal leakage after pelvic surgery, a double dye test may differentiate between VVF and UVF [123]. To perform this test, the vagina is packed, and methylene blue is given intravenously; red carmine is instilled intravesically. The vaginal pack will stain red if a VVF is present and blue if a UVF is present. An intravenous urogram or CT-IVP will demonstrate varying degrees of hydronephrosis (Fig. 20.7) and may demonstrate an occasional silent kidney [124]. If imaging fails to reveal the fistula, a retrograde ureteropyelogram will usually demonstrate the location and magnitude of the fistula.

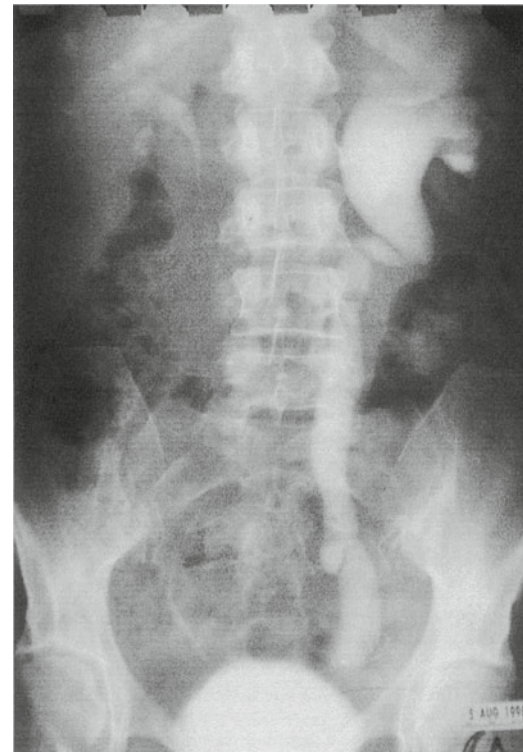

Fig. 20.7 An intravenous urogram will demonstrate varying degrees of hydronephrosis

Management

The objectives in management of a UVF are to preserve renal function, prevent or treat urinary sepsis, and cure the incontinence. Treatment options include observation, internal drainage via ureteral stent, external drainage via percutaneous nephrostomy, open surgical repair, and nephrectomy. However, controversy surrounds the role,

if any, of protective nephrostomy drainage and the timing of surgical intervention. Some surgeons advocate immediate surgical repair of the damaged ureter once the diagnosis is certain; although others advocate early drainage of the upper tract followed by delayed ureteral repair [13, 125–130]. There are reports of spontaneous healing of UVFs [13, 121, 131].

When the diagnosis of UVF is made, the surgeon must define the degree of ureteral obstruction distal to the fistula site. If distal ureteral obstruction remains, spontaneous healing of the fistula is extremely unlikely. The recommendation for both diagnostic and therapeutic reasons is to perform ureteral catheterization in addition to retrograde ureteropyelography. If a ureteral catheter is unable to be passed, the diagnosis of a distal obstruction is confirmed. If a stent can be placed to bypass the fistula, spontaneous healing is likely without further intervention [131–133]. The best-suited patients for nonsurgical management are those with unilateral ureteral injury, documented ureteral continuity, mild-to-moderate obstruction, and minimal extravasation. It is advantageous to attempt ureteral stenting to ensure decompression of the renal unit while simultaneously increasing the chance of healing. Conservative management has been successful when the above radiographic criteria were met, even when ureteral stenting failed [131]. In a patient who is nonoperatively managed, upper tract improvement and resolution of ureteral extravasation need to be documented on follow-up evaluation.

Endoscopic Techniques

Successful ureteral stenting may be achieved through several recently described endourological techniques. One option is the use of rigid ureteroscopy with low-flow irrigation to pass a 0.89-mm Glide wire retrograde across the ureteral injury [133, 134]. The advantage of ureteroscopy is direct visualization of the wire and improvement of the fulcrum at the level of the ureteral orifice, which increases the likelihood of achieving stenting.

If retrograde ureteral stenting is unsuccessful, antegrade percutaneous nephrostomy drainage may be attempted under local anesthesia. By placing the nephrostomy, the obstruction is relieved, and access for antegrade ureteral intubation is made available. Percutaneous nephrostomy is the first choice for a patient with infection or one who is too ill for general anesthesia or retrograde manipulation. A period of observation after percutaneous nephrostomy to allow for spontaneous healing of the damaged ureter is advocated by some [135, 136]. The spontaneous healing rate in highly selected individuals is reported as greater than 50 % following nephrostomy [135, 136].

In the majority of patients, a prolonged course of external drainage is less than desirable and antegrade stenting on an elective basis is recommended. In the event that antegrade stenting fails, a combination of antegrade-retrograde stenting technique may succeed. After passing one to two antegrade wires, cystoscopic removal of the bladder wire is performed. When tension is applied to both ends of the working wire, a retrograde ureteral stent is often able to pass across the fistula. Once a stent is placed, there is a 50–70 % chance that the UVF will heal without the need for open surgical intervention [133, 135–137]. In a study by Selzman et al. [137], eight women with UVFs underwent stent placement. All except one had the stent left in place for 4–8 week. All 7 patients had resolution of the fistula when the stent was left in for this amount of time and the ureter was given the chance to heal. The only complication was one stricture, which developed after stent removal and was repaired endoscopically. Because of the chance of ureteral stricturing, close follow-up is needed [131].

Surgical Repair

If neither antegrade nor retrograde ureteral access is achievable or even an option, open surgical repair is indicated. Controversy regarding the timing of the fistula repair is present because it is a reoperative procedure. Some surgeons recommend a “cooling down” period to allow the inflammation to resolve. In this instance, a percutaneous nephrostomy is performed to allow for drainage of infection and to protect the kidney [130, 138]. Some advocate nephrostomy only in the face of azotemia and urosepsis [121]. Drainage of the upper tract will not

necessarily solve the incontinence because some urine will proceed down the ureter and out the vagina through the fistula.

During a laparoscopic case, the chance of thermal injury to the ureter is a possibility, which may turn a less-invasive case into a debilitating one. In these circumstances, bipolar electrocautery is safer than unipolar because it reduces thermal spread [117]. To take this a step further, bipolar scissors are recommended over 5-mm forceps because it is thought they allow energy to be applied more accurately [115].

Should a thermal injury to the ureter occur and there is no urine extruding from one ureteral orifice on cystoscopy, a double-J stent should be placed for 6 week. This course of action is based on the belief that a burned ureter develops immediate mucosal edema that prevents urine passage. The double-J stent prevents fistula formation by diverting the urine while the ureter has a chance to heal. If cystoscopy reveals that a stent should be placed, even if the ureter is not really damaged, no harm is done. However, if a thermally injured ureter is not stented, a fistula with its related morbidity may form [117].

A movement toward early repair of the UVF is made because it involves a great deal of distress for the patient and anxiety for the surgeon. Early surgical repair may be undertaken if there is no significant urosepsis and renal function is relatively well preserved [123–125, 139]. Goodwin and Scardino were the first to demonstrate that early repair is achievable with excellent results [13].

Operative repair of the UVF is governed by several principles. Little attempt should be made to confine the surgery extraperitoneally, continuity between a normal ureter and bladder should be reestablished, and adequate drainage should be maintained [124]. Ureteroneocystostomy involves a bypass of the site of ureteral injury, eliminating the need for direct localization of the injured ureter by a difficult dissection [127]. It is the favored repair because most fistulas occur in the distal third of the ureter. On occasion, end-to-end ureteroureterostomy may be performed [121, 122, 126], but only in the case of limited inflammation and ureteral loss, so that as much of a tension-free anastomosis may be created as possible. However, ureteroureterostomy is generally not preferred in cases of distal ureteral injury due to concerns regarding insufficient vascular supply that could predispose to stricture.

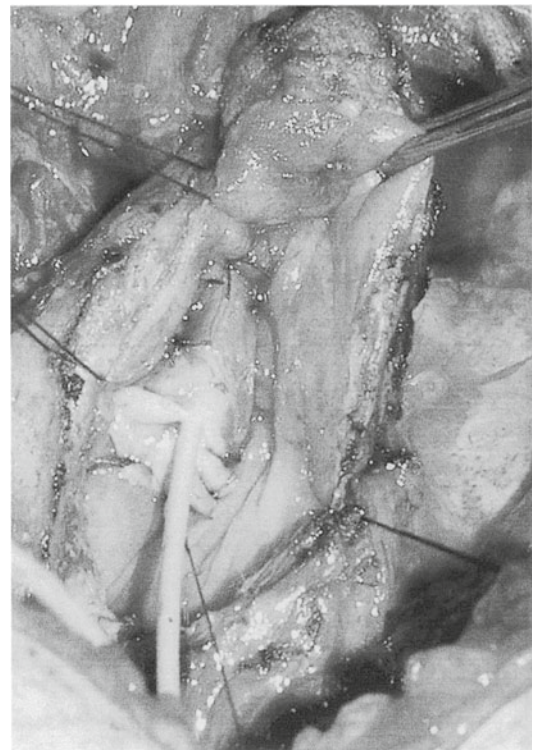

Fig. 20.8 A psoas bladder hitch

The length of the ureteral segment needed to bypass, which depends on the location of the injury and obstruction, and the degree of ureteral and bladder mobility, will dictate the method of reimplantation. In the majority of cases, a direct ureteroneocystostomy can be performed, often aided by a psoas bladder hitch (Fig. 20.8) to relieve any tension of the anastomosis [119, 121, 128, 140]. The majority of reports revealed that, by using sound surgical principles, almost 100 % success can be achieved with ureteral reimplantation [119, 121, 125, 128, 137, 141]. Goodwin and Scardino [13] recommended using an antireflux submucosal tunnel in each patient; others did not feel this measure is necessary [113, 119]. Many believe that ureteroneocystostomy without the use of an antirefluxing anastomosis lowers the risk of postoperative ureteral obstruction.

If the injury to the ureter is distal, a vesicopsoas hitch is usually sufficient to render the anastomosis free of tension. A Boari flap replacement of the distal ureter may be employed when the obstructive segment lies proximally or when there are multiple sites of obstruction. A Boari flap is also used in the face of a pelvic abscess cavity, which allows the surgeon to perform the anastomosis of the ureter to the bladder away from any foci of infection [121]. A report by Falandry of 14 cases of UVF repair with a cuffed reimplantation with a tubular bladder plasty demonstrated no anastomotic stenosis or leak [141]. In the instance of high or long ureteral strictures, a more complex reconstruction such as transureteroureterostomy, renal decensus, renal autotransplantation, or ileouretero-cystoplasty may be necessary. The more specific details of these surgical procedures are covered in Chap. 4 ureteral trauma.

Conclusion

UVF is a rare complication of pelvic surgery, most often following total abdominal hysterectomy for benign disease and radical hysterectomy for malignancy. Some degree of distal obstruction with concomitant transmural injury results in constant urinary extravasation, with fistulization to the vaginal cuff. Urinary incontinence usually follows 1–4 week postoperatively without previous symptoms. Intravenous urogram or CT-IVP and ureteropyelography are adequate studies to demonstrate the location of the injury and the degree of distal obstruction and to provide information necessary to formulate an appropriate plan of treatment. The goals of treatment center on renal preservation, treatment of urosepsis, relief of any obstruction, and alleviation of incontinence.

Advances in endourological procedures have made retrograde or antegrade ureteral stenting prudent in patients with unilateral injury, only mild-to-moderate obstruction, minimal extravasation, and some demonstrable ureteral continuity. Percutaneous nephrostomy is indicated in patients with complete ureteral obstruction or obstruction with simultaneous infection. Patients who are not candidates for ureteral stenting and who fail conservative management need definitive surgical repair. The procedure of choice is reimplantation of the healthy ureter into a mobilized bladder. In the event of a proximal ureteral injury, a psoas hitch, Boari flap, or even transureteroureterostomy or ileal ureteral replacement may be required. Percutaneous ureteral occlusion or nephrectomy should only be used as a last resort.

Summary

Iatrogenic injuries are a well-described complication of gynecological surgery. The proximity of the ureters and the bladder to the cervix and anterior vaginal wall render them susceptible to injury during gynecological and pelvic operations. Iatrogenic injury, if unrecognized and untreated, can result in VVF or UVF—an anomalous communication between the bladder or ureter and the vagina. The avoidance, recognition, and subsequent treatment of these complications are important issues, given the morbidity suffered by the patient and the medicolegal implications realized by the surgeon.

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Management of the Ureter During Pelvic Surgery

21

Noel A. Armenakas

Epidemiology and Pathogenesis of Iatrogenic Ureteral Injuries

The ureter is vulnerable to inadvertent injury during operations within the pelvis and retroperitoneum because of its inconspicuous retroperitoneal location and close association to the iliac vessels, colon, and uterus. In addition, various abdominal disease processes can affect the normal ureteral course, causing it to deviate, making it more difficult to identify. Iatrogenic injuries to the urinary tract during abdomino-pelvic surgical procedures most commonly involve the bladder, followed by the ureter. Most contemporary series report the incidence of iatrogenic ureteral injuries at 0.1–2.9 % [1–4]. Factors that predispose to such injuries are listed in Table 21.1. Mechanisms of ureteral injury include crushing, angulation, electrocoagulation, devascularization, ligation, perforation, transection, and excision.

Historically, the majority of iatrogenic ureteral injuries occurred during gynecologic procedures, most frequently during abdominal hysterectomies (Table 21.2) [5–14]. During the past 25 years, with the advent of ureteroscopic surgery, urologic procedures account for most ureteral injuries. Fortunately, the majority of these are minor, such as mucosal false passages and small perforations, and can be successfully managed with ureteral stenting. Radical prostatectomy (open or robotic/laparoscopic) infrequently results in ureteral trauma. In contemporary series the reported incidence of such injuries is 0.1–1.6 % [15, 16].

Other operations which may injure the ureter include general surgical procedures such as low anterior colon and rectal resections, vascular procedures, including aortoiliac and aortofemoral arterial bypass surgery, and less frequently, spinal and orthopedic surgeries [17–20].

Injury Prevention

Awareness of the ureter's anatomical course and areas of greatest susceptibility to trauma is important in preventing iatrogenic injuries. Most iatrogenic ureteral injuries involve the lower third of the ureter. The ureter should be routinely identified and appropriately exposed, as needed, to ensure direct visualization. Cosmetic minimalistic incisions that limit surgical exposure may compromise ureteral identification.

During gynecological and obstetrical procedures the most common site of a ureteral injury is at the pelvic brim where the ovarian vessels cross the ureter in the infundibulopelvic ligament (also known as the suspensory ligament of the ovary). Other common locations include the iliac arteries, within the cardinal ligament at the level of

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Table 21.1 Factors that predispose to iatrogenic ureteral injury

Prior surgery
Infection or inflammation (such as diverticulitis, pelvic inflammatory disease, endometriosis)
Radiation therapy
Malignancy
Uterine size >12 weeks gestation
Ovarian mass >4 cm
Obesity
Massive bleeding
Congenital anomalies (ureteral duplication, retrocaval or ectopic ureter, horseshoe or pelvic kidney)

Table 21.2 Causes of iatrogenic ureteral injury, by procedure

Series	Gynecologic	Urologic	Colon	Vascular	Spinal	Total
Higgins (1967)	60	5	12	7	2	86
Ihse (1975)	23	13	6	0	0	42
Dowling (1986)	14	8	3	1	1	27
Gangai (1986)	9	10	3	0	2	24
Assimos (1984)	11	12	4	0	0	27
Seltzman (1996)	56	70	28	10	1	165
Parpola–Sparma (2008)	46[a]	8	18	0	0	72
Total	*219* (49.4 %)	*126* (28.4 %)	*74* (16.7 %)	*18* (4.1 %)	*6* (1.4 %)	*443*

[a]Eighty-two percent occurred during laparoscopy

the internal cervical os, and at the anterolateral fornix of the vagina as the ureter enters the bladder (Fig. 21.1) [21]. During colorectal procedures, iatrogenic ureteral injuries usually occur at the take-off of the inferior mesenteric artery or between the lateral rectal ligaments. Besides direct injury to the ureter, entrapment of the ureter in perianeurysmal fibrosis can occur as a consequence of vascular procedures.

Ureteral Stenting

The use of intraoperative stents in identifying the ureters and preventing inadvertent injury has been evaluated extensively [22–27]. Although intuitively ureteral stenting prior to a major abdomino-pelvic operation can aid in tactile ureteral localization and possibly injury avoidance or early injury recognition, a clear advantage has not been established. In general, the results of multiple studies evaluating the efficacy of preoperative ureteral stenting are equivocal. A possible explanation for this is the low overall incidence of ureteral injuries with any procedure; hence, a very large number of subjects would be needed to sufficiently power any study and provide accurate confidence intervals. In addition, complications of ureteral stents should not be overlooked. These include various degrees of patient discomfort, infection, bleeding, obstruction, stent encrustation, and migration.

In conclusion, the inherent limitations of the available studies, the potential complications, and added cost of routine stenting suggest that they should be used selectively based on the surgeon's preference and judgment. Universal routine stenting prior to major abdomino-pelvic procedures is not advised.

Injury Recognition and Evaluation

Prompt injury recognition is the first step towards a successful outcome. A delay in diagnosis complicates management and increases morbidity.

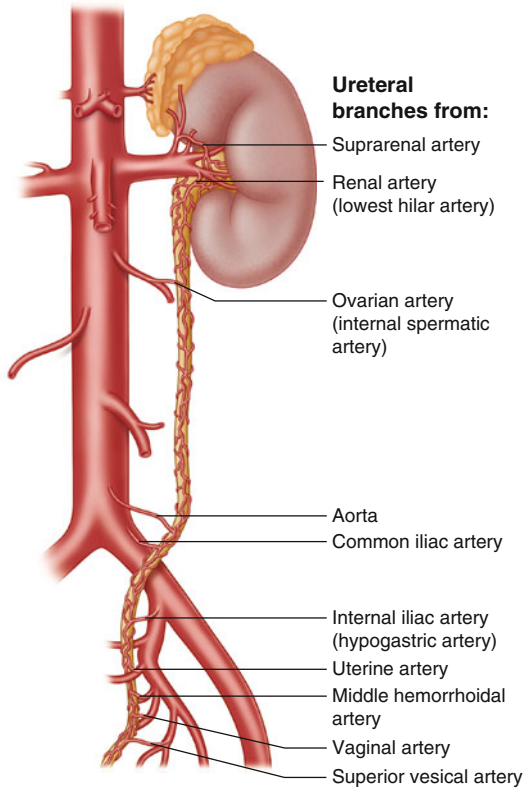

Fig. 21.1 Ureteral vascular branches. The upper ureter receives its blood supply mainly from the renal arteries, its midportion from the aorta and iliac arteries, and the lower segment from the superior and inferior vesical, middle hemorrhoidal, and uterine arteries

An injury identified intraoperatively, in a stable patient, should be addressed at that time. The postoperative presentation of a ureteral injury can be elusive resulting in a further delay in diagnosis. Delayed signs or symptoms of a ureteral injury most commonly include abdominal or flank pain, fever, ileus, urinary leakage, azotemia, and eventually, sepsis. After abdominal or pelvic surgery, any patient who is suspected of having a ureteral injury should be thoroughly evaluated.

Less than half of iatrogenic ureteral injuries are identified immediately (Table 21.3) [6, 7, 10–12]. Laparoscopic injuries result in the highest incidence of delay [11, 28–30]. This can be attributed to the mechanism of these injuries, usually by electrocoagulation or ligation, which can lead to delayed tissue necrosis and, consequently, delayed recognition.

Table 21.3 Injury recognition in iatrogenic ureteral injury

Series	Immediate	Delayed	Total
Ihse (1975)	11	33	42
Dowling (1986)	4	23	27
Daly (1988)	8	8	16
Selzman (1996)	85[a]	80	165
Parpola–Sparman (2008)	15	57	72
Total	*123* (61.8 %)	*199* (38.2 %)	*322*

[a]Primarily urological injuries

Intraoperative

Direct visual inspection is the most reliable method of assessing ureteral integrity intraoperatively. If a ureteral injury is suspected, the ureter should be identified, carefully mobilized, and adequately exposed along its course. Reliable intraoperative findings, suggestive of a ureteral injury include: ureteral discoloration or bruising, lack of ureteral bleeding, urinary extravasation, or the presence of a suture or surgical clip in the proximity of the ureter. More subtle findings include decreased ureteral peristalsis and ureteral dilation. Intraoperative recognition can be facilitated by the intravenous or intraureteral injection of indigo carmine or methylene blue. This should be used as a last step in the intraoperative evaluation of the ureter as the blue dye may obscure the surgical field, in cases of complete ureteral transection or excision. The absence of dye in the operative field does not rule out a ureteral injury.

Radiographic

Postoperatively, ureteral injuries are often suspected on a CT scan prompted by changes in the patient's clinical status. Characteristic CT findings include hydroureteronephrosis, focal ureteral dilation, urinoma, abscess, or ascites. Rapid sequence spiral CT scans may not provide an adequate excretory phase. In such cases, a repeat CT should be performed 15–20 min after the initial study to assess ureteral filling. Coronal CT cuts are helpful in better visualizing the injury. Periureteral contrast extravasation without distal ureteral opacification on delayed CT images is

the *sine qua non* of a complete ureteral transection. Ureteral contusions provide more subtle radiographic findings ranging from ureteral dilation to a completely normal study.

Confirmation of a ureteral injury is best achieved with ureteropyelography. It is the most sensitive imaging test, because of the high concentration of intraureteral contrast material provided. However, in an intraoperative situation, ureteropyelography may be impractical as it often requires repositioning of the patient and the need for endoscopic equipment.

Anatomic Surgical Considerations

Familiarity with the anatomic features of the ureter is important in limiting iatrogenic injury and planning surgical strategies for repair. The ureter serves as the sole source of urinary transport from the kidney. Any injury to this delicate tubular structure poses a potential risk to the ipsilateral renal unit. The ureter is a thick-walled narrow tube measuring approximately 25–30 cm in length and varying in diameter from 2 to 10 mm. It has three distinct layers: an outer adventitial sheath, through which the vessels course, a medial layer made of longitudinal and circular smooth muscle fibers, and an inner mucosal lining consisting of transitional epithelium. The ureter derives its blood supply from an anastomotic network, within the adventitia, arising from multiple vessels. During ureteral dissection, it is imperative to maintain the integrity of the adventitial sheath in order to avoid injury to its vascular, nerve, and lymphatic supplies.

The upper ureter receives its blood supply mainly from the renal arteries, its midportion from the aorta and iliac arteries, and the lower segment from the superior and inferior vesical, middle hemorrhoidal, and uterine arteries (Fig. 21.1). The vessels to the upper two thirds and lower third of the ureter emanate medially and laterally, respectively. Since these vascular sources can be variable, ureteral dissection always should be performed cautiously to avoid inadvertent devascularization. In general, the peritoneal incision for exposure of the upper two thirds of the ureter should be made laterally and medially for the lower third. Excessive ureteral dissection and mobilization should be avoided in order to limit sacrificing perforating arterial branches.

Additional obstacles which need to be recognized during ureteral identification and dissection include ureteral anomalies which may alter its course (retrocaval, ectopic), size (megaureter, diverticulum,) or number (duplication).

Within the pelvis, the ureters cross anterior to the iliac vessels at the level of the common iliac bifurcation. This location provides a valuable landmark for ureteral identification during pelvic procedures. The ureters then diverge laterally before turning anteromedially to insert into the bladder.

In the female, the pelvic portion of the ureter courses posterior to the infundibular pelvic ligament and then passes anteromedially at the base of broad ligament, lateral to the uterosacral ligament (Fig. 21.2). At this level the ureter is crossed anterosuperiorly by the uterine artery; this occurs 1.5 cm lateral to the uterus, but can vary markedly when pathologic conditions have distorted the anatomic relationships. The ureter continues distally, coursing medially, and then passing anterior to the vagina prior to traversing the bladder wall obliquely. The ovarian vessels cross the iliac vessels anterolateral to the ureter; injury to the ureter can occur during dissection of these vessels at the pelvic brim [31].

In the male, the pelvic ureter courses anterior to the obturator vessels. It then runs medially with the inferior vesical neurovascular bundle, passing posterior to the vas deferens prior to entering the bladder [32].

Management Concerns

Management Selection

Iatrogenic injuries are usually amenable to a wide range of management options. Prompt identification and appropriate management of the injured ureter is important in avoiding postoperative morbidity. Selection of the appropriate

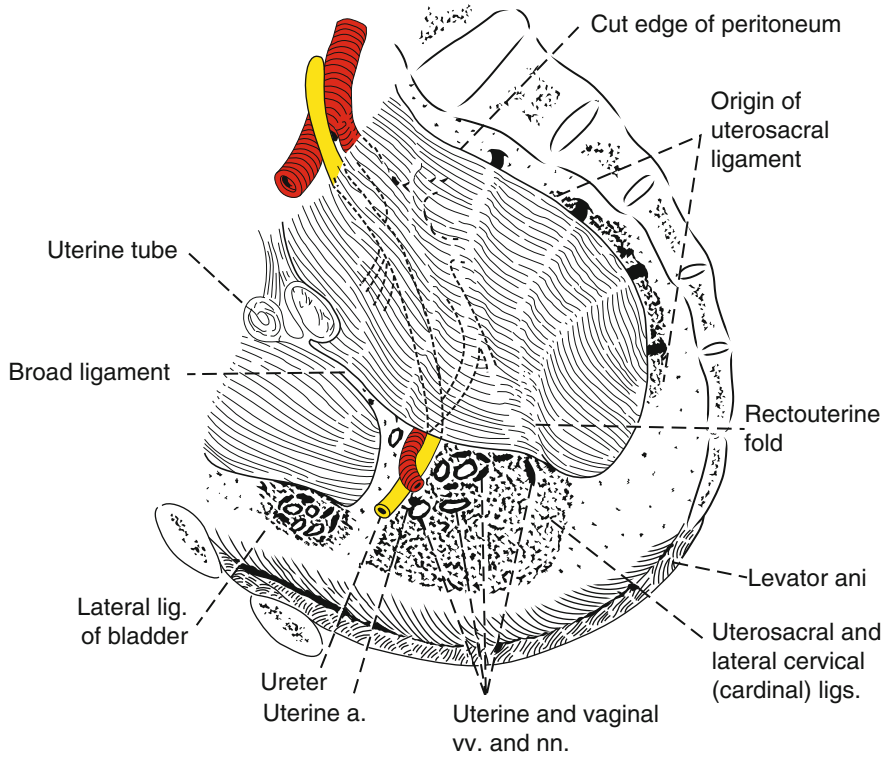

Fig. 21.2 Female pelvic ureteral anatomy

Table 21.4 Outcome of iatrogenic ureteral injuries managed with percutaneous nephrostomy drainage or ureteral stenting

Series	Total number of patients	Percutaneous nephrostomy or stent	No subsequent treatment
Assimos (1994)	19	12	5 (41.7 %)
Lask (1995)	44	20	16 (80.0 %)
Ku (2003)[a]	30	17	11 (64.7 %)
Total	*93*	*49*	*32 (65.3 %)*

[a]OB/GYN injuries only

treatment depends on the patient's overall condition (including any associated organ injuries), promptness in injury recognition, and the location and extent of the ureteral injury. If suspected intraoperatively, the injured ureter should be carefully inspected for evidence of transection or ischemia. Concomitant intraabdominal organ or vascular injuries should not preclude ureteral reconstruction in an otherwise stable patient [17, 33–35]. In these cases, the appropriate reconstructive procedure can be safely performed and an omental flap interposed to protect the repair.

Temporary Urinary Diversion

Ureteral injuries with a significant delay in diagnosis, or in an unstable patient, are best managed initially by percutaneous nephrostomy drainage or endoscopic ureteral stenting. Percutaneous nephrostomy placement is safer and more universally applicable, whereas retrograde ureteral stenting should be limited to partial transections. In many cases these minimally invasive endourologic techniques alone will result in resolution of the ureteral injury (Table 21.4) [9, 10, 36, 37].

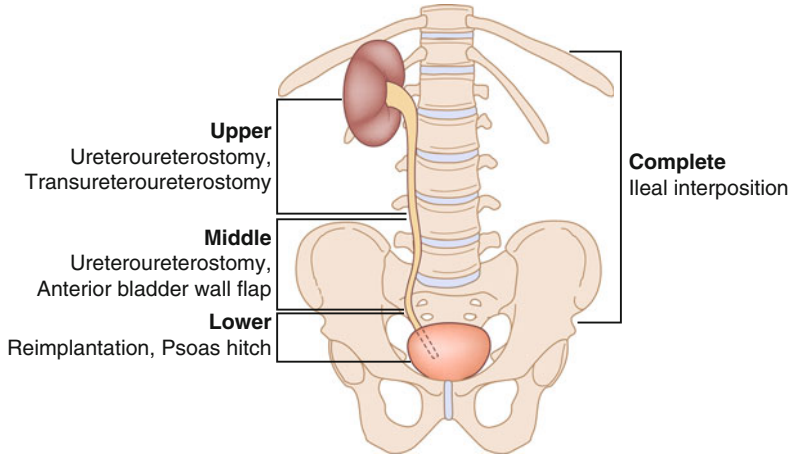

Fig. 21.3 Ureteral reconstructive techniques by injury location

In an intraoperative situation where a complete ureteral transection is identified but the patient's precarious condition does not permit immediate ureteral reconstruction, ureteral ligation with placement of a percutaneous nephrostomy tube serves as an expedient "bail-out" procedure. Open nephrostomy should not be used since this is more invasive and consumes precious operating time, further jeopardizing patient outcome. An alternative intraoperative option, in the unstable patient, is the creation of a cutaneous ureterostomy. This may be used during damage control surgery where the procedure must be abbreviated to allow for reversal of coagulopathy and metabolic derangements associated with major hemorrhage. Once the patient is stabilized and returned to the operating room, definitive repair of all previously temporized injuries can be accomplished. This approach is more commonly employed in victims of external trauma.

Most complete ureteral transections require reconstruction. This should be delayed until the patient has healed from any associated injuries. Traditionally, reconstructive surgery is deferred for a period of 8–12 weeks to allow for resolution of the acute periureteral inflammatory response. This recommendation is based solely on expert opinion with the option for early intervention in select patients [38, 39]. The appropriate procedure should be planned only after compiling the necessary functional and anatomic radiographic information. Besides antegrade and/or retrograde ureteral imaging, a cystogram should always be obtained when the bladder is being considered for the reconstructive procedure.

Ureteral Reconstructive Techniques

General principles of ureteral reconstruction include careful debridement, creation of a watertight tension-free spatulated anastomosis, use of absorbable suture material to prevent stone formation, isolation of the anastomosis from associated injuries, and adequate ureteral and retroperitoneal drainage. Minimal handling of the adventitia and careful periureteral dissection are paramount in preserving ureteral vasculature. Devitalized tissue should be debrided carefully ensuring bleeding from the cut ureteral ends. The appropriate reconstructive procedure should be performed, based on the location and extent of the ureteral injury (Fig. 21.3). This information is obtained from the imaging modalities. However surgical exploration may reveal less viable ureter for reconstruction than anticipated. This potential discrepancy between the radiographic and surgical findings should be anticipated and more than one treatment option planned.

Most ureteral injuries are reconstructed using open surgical techniques. With additional experience and advances in laparoscopic and robotic surgery, small case series are emerging utilizing these minimally invasive modalities to reconstruct the injured ureter. Examples of procedures performed laparoscopically include ureteral reimplantation, ureteroureterostomy, and anterior bladder wall flap reconstruction [40–44]. The choice of laparotomy or laparoscopy should be dependent on the surgeon's familiarity and comfort with each option. In both cases, the basic principles of ureteral repair must be implemented.

If the ureteral injury is identified intraoperatively, it can be reconstructed through the same incision. Extension of the incision or conversion from a laparoscopic to an open approach should be considered when necessary to optimize ureteral exposure.

With planned ureteral reconstruction, the incision can be tailored to the specific procedure. In general, a midline abdominal incision allows complete exposure of the ureter and bladder. Alternatively, select proximal or distal ureteral injuries can be exposed through a subcostal or Gibson incision, respectively.

Optical loupe magnification is helpful in achieving optimal suture placement with open surgery. Maintaining ureteral vascularity minimizes postoperative stricture and fistula formation.

With concomitant intraabdominal organ injuries that cause fecal or other bacterial contamination, the greater omentum can be used to exclude the ureter and protect the repair. A pedicle flap based on the right or left gastroepiploic vessels is created by dissecting the greater omentum off the greater curvature of the stomach. The short gastric vessels are then divided and the flap is transferred retroperitoneally and wrapped around the ureteral anastomosis, isolating it from the abdominal contents. For bilateral ureteral injuries, bilateral omental flaps can be fashioned based on the right and left gastroepiploic vessels.

A description of the various surgical techniques follows [45].

Disligation

Select iatrogenic injuries, due to inadvertent ureteral ligation, that are identified intraoperatively can be managed simply by suture removal. Once this is accomplished, the ureter must be observed carefully for any signs of devascularization, and undergo placement of a stent. If there is any suggestion of irreversible ischemia, the involved segment should be excised so that the appropriate reconstructive procedure can be performed.

Primary Closure

Select simple iatrogenic ureteral lacerations without devitalization, when identified promptly, can be managed by primary closure. Interrupted fine absorbable sutures are used to carefully reapproximate the ureteral wall and a ureteral stent placed to protect the repair. Care is taken to avoid inadvertent narrowing of the suture line, if possible closing the ureterotomy transversely.

Reimplantation

Injuries to the distal third of the ureter are best managed by simple reimplantation. This is done using a combined intra- and extra-vesical approach, bringing the ureter through the posterior bladder wall just medial to the original hiatus. When possible, a submucosal tunnel can be created based on the standard 3:1 ratio (tunnel length: ureteral diameter), although this is unnecessary in the adult patient as vesicoureteral reflux is inconsequential. Ensuring a tension-free anastomosis always supersedes creation of a tunneled reconstruction. The distal ureter is spatulated and secured to the bladder wall with interrupted fine absorbable sutures. The repair is stented and the bladder closed in two layers. Attention to adequate ureteral mobilization without excessive adventitial dissection or ureteral kinking will limit potential postoperative problems, including obstruction and extravasation.

Psoas Hitch

Injuries involving the entire lower third of the ureter are best managed by a psoas hitch in conjunction with ureteral reimplantation. When the reconstruction is performed electively, a preoperative cystogram is useful in assessing bladder capacity.

The proximal ureteral end is debrided and a traction suture placed to facilitate handling. The bladder fundus is mobilized by dissecting it away from the peritoneal reflection. The contralateral superior vesical pedicle is ligated; when needed, bilateral superior pedicle ligation affords improved bladder mobilization. An oblique anterior cystotomy is then made, perpendicular to the involved ureter. Using the index and middle fingers, the bladder dome is guided over the ipsilateral iliac vessels towards the psoas tendon and anchored to this with interrupted sutures. Care is taken to avoid entrapping the genitofemoral nerve. The ureter is reimplanted, as previously described. The bladder wall is closed perpendicular to the cystotomy, in two layers, leaving a suprapubic tube for drainage.

Anterior Bladder Wall Flap

Injuries encompassing the entire lower two thirds of the ureter are best managed with an anterior bladder wall (Boari) flap, in conjunction with a psoas hitch. Reconstructive procedures that incorporate the bladder should not be used in patients with prior pelvic irradiation, neurogenic bladder disease, or a history of bladder cancer.

The bladder is mobilized as previously described, and a full thickness U-incision is made in its anterior wall; for longer defects, additional length can be obtained using an L-configuration. The width of the flap should be approximately 3–4 times the ureteral diameter, maintaining a wider base to ensure an adequate blood supply. The flap is raised towards the involved ureter and the bladder wall hitched to the ipsilateral psoas tendon. The ureter is reimplanted submucosally into the flap, which is then closed in a tubularized configuration. Bladder closure is completed as previously described. Accurate flap dissection with maintenance of a wide base can minimize flap complications and avoid significantly decreasing bladder capacity.

Using this technique, ureteral defects of up to 15 cm can be easily bridged. Longer defects can be further decreased by up to 3–4 cm by performing a reverse nephropexy. This is accomplished by dissecting the kidney away from Gerota's fascia and fixing the renal capsule, caudally, to the underlying retroperitoneal muscles. Extensive dissection or tension can result in renal hemorrhage or vascular injury, respectively.

Ureteroureterostomy

Most complete ureteral transections involving the middle or upper third of the ureter, with defects limited to 2 cm, are best managed by primary ureteroureterostomy. This technique can be also used for clamp injuries which often produce significant crush damage requiring excision of any devitalized segment and ureteral reanastomosis.

The ureteral ends are carefully dissected and debrided to viable tissue. Each end is spatulated, on opposite sides, and a watertight tension-free anastomosis is fashioned, over a ureteral stent, using fine absorbable sutures.

Transureteroureterostomy

Injuries involving the distal half of the ureter, with insufficient bladder capacity or severe pelvic scarring, can be managed with a transureteroureterostomy. The posterior peritoneum is incised exposing both ureters. The diseased ureter is carefully brought through a retroperitoneal window, avoiding any angulation. A 1.5 cm longitudinal ureterotomy is made on the medial surface of the recipient ureter and an end-to-side anastomosis is created with interrupted fine absorbable sutures. The donor ureter should course above the inferior mesenteric artery to avoid inadvertent ureteral impingement.

This procedure can potentially jeopardize the integrity of the normal ureter or pelvis and should

be used selectively. In addition, it is contraindicated in patients with upper tract transitional cell carcinoma or recurrent urolithiasis.

Ileal Interposition

For complete ureteral replacement, in select patients, a segment of ileum may be interposed as a ureteral substitute. This procedure is usually performed electively and not as an emergency. It should be considered only in patients with relatively normal renal function (serum creatinine <2.5 mg/dL).

A 20–25 cm segment of ileum is chosen, 15 cm proximal to the ileocecal junction. The bowel mesentery is divided, maintaining vascular integrity, and the appropriate segment of ileum resected using a linear anastomotic stapler. Bowel continuity is resumed by creating a stapled functional end-to-end enteric anastomosis; the mesenteric window is closed to prevent internal visceral herniation. The ileal neoureter is then positioned posteriorly, in an isoperistaltic fashion. An end-to-end pyeloileal anastomosis is completed, using a nephrostomy to maintain a low-pressure system during healing. Distally, the ileal segment is anastomosed to the bladder dome. In extensive bilateral ureteral injuries, a segment of ileum can be tailored as a conduit for both kidneys [46–50].

Potential long-term complications of ileal interposition include hyperabsorption of electrolytes (manifested by hyperchloremic metabolic acidosis), anastomotic strictures, fistulas, obstruction, prolonged mucous formation, recurrent infection, and ischemic ileal necrosis.

Drainage Issues

All ureteral injuries should be stented to maximize urinary diversion. An internal double-J or exteriorized pediatric feeding or single-J tube can be used for this purpose. A retroperitoneal drain should be placed at the site of reconstruction to limit urinoma formation. Some surgeons prefer a passive drain, since closed suction drains can prolong leakage by exerting negative pressure on the suture line. The bladder should be decompressed using a transurethral or suprapubic catheter, alone or in combination. The retroperitoneal drain is maintained for at least 48 h, or until urinary extravasation subsides. The bladder catheter(s) is removed in 2–7 days, depending on the type of ureteral repair and the extent of bladder dissection. The ureteral stent usually is maintained for 4–6 weeks. In cases where stent-induced reflux can compromise the ureteral reconstruction, prolonged bladder catheter drainage should be considered.

Postoperative Evaluation

Ureteral patency and renal function are evaluated, once the patient is tube-free, using CT urography, intravenous urography, or radionuclide scanning. Renal imaging should be repeated at 3 and 6 months to ensure proper healing, preferably with sonography to avoid additional radiation exposure. In addition, periodic assessment of blood chemistries is essential after ileal interposition, to identify any potential metabolic complications.

Complications

Complications of ureteral injuries include prolonged urinary extravasation, infection, urinoma, fistula (including vesicovaginal and ureterovaginal), and stricture. Progressive renal failure with acidosis and upper urinary tract decompensation can complicate a failed repair. Complications specific to each reconstructive procedure are discussed in the "Ureteral Reconstructive Techniques" section.

Summary

Prevention of surgical ureteral injury is the goal. Knowledge of ureteral anatomy and location at all times during abdominal or pelvic surgery is paramount in avoiding inadvertent injury to the ureter.

When a ureteral injury is suspected during surgery, vigilant intraoperative inspection and immediate implementation of corrective measures will minimize complications. With all ureteral injuries the clinical and radiographic evaluations are often indeterminate and, consequently, maintaining a high index of suspicion is essential in making the diagnosis promptly. A delay in diagnosis is the most important contributory factor in morbidity related to ureteral injury.

Many ureteral injuries will heal simply with urinary diversion alone avoiding the need for subsequent surgical intervention. Where necessary, the timing of repair of the ureteral injury is based on the patients overall condition, promptness of injury recognition, type of ureteral injury, and the urologic surgeon's judgment and expertise. In an unstable patient, restoring hemodynamic and metabolic stability takes precedence over definitive ureteral repair. Successful surgical management, whether performed immediately or in a delayed fashion, requires familiarity with the broad reconstructive armamentarium, as well as meticulous attention to the specific details of each procedure. Adhering to these diagnostic and therapeutic principles will serve to minimize complications and maximize renal preservation in patients sustaining ureteral injuries.

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Part VI

Pediatric Urological Emergencies

The Exstrophy–Epispadias Complex 22

Richard W. Grady

Introduction

Children born with congenital anomalies in the exstrophy–epispadias complex include children with:

- Epispadias
- Classic bladder exstrophy
- Cloacal exstrophy
- Exstrophy variants

These congenital defects are considered pediatric urologic emergencies because early repair (less than 48–72 h of age) has historically been done more easily, more cost-effectively, and with better outcomes than in a delayed fashion [1, 2]. Newborn repair is associated with improved success rates compared to exstrophy repair later in life [3]. Because the bladder exstrophy–epispadias complex is not a lethal condition, children with bladder exstrophy or epispadias can and do survive untreated. Before the modern era of surgery and anesthesia, many patients with bladder exstrophy survived untreated into adulthood. Reports exist of such patients with classic bladder exstrophy living into their eighth decade [4]. However, the morbidity untreated bladder exstrophy patients experience includes bladder and kidney infection, skin breakdown, and eventual tumor formation in the bladder plate. In contrast, until recently patients born with cloacal exstrophy routinely died shortly after birth from electrolyte abnormalities and malnutrition.

Anatomic Features

The classic primary features of exstrophy involve an absence of the anterior bladder wall and dorsal urethra with an associated absence of the anterior abdominal wall overlying it (Fig. 22.1). The urothelium of the bladder and urethra is thus exposed to the environment. With cloacal exstrophy the cecal plate is also exposed to the environment and rests between two bladder halves (Fig. 22.2). Considerable variation exists in the size and compliance of the bladder plate at birth; some bladders are quite small and inelastic whereas others appear large and compliant. At birth, the urothelium is usually normal in appearance. However, ectopic bowel mucosa or polypoid lesions consistent with cystitis cystica and/or glandularis may be present. If left untreated and without meticulous protection after birth, the exposed urothelium will undergo squamous metaplasia in response to acute and chronic inflammation. Other inflammatory changes such as cystitis cystica and/or glandularis will also be seen. When left chronically exposed to the environment, the areas of squamous metaplasia often undergo malignant degeneration to adenocarcinoma or squamous cell carcinoma [4, 5].

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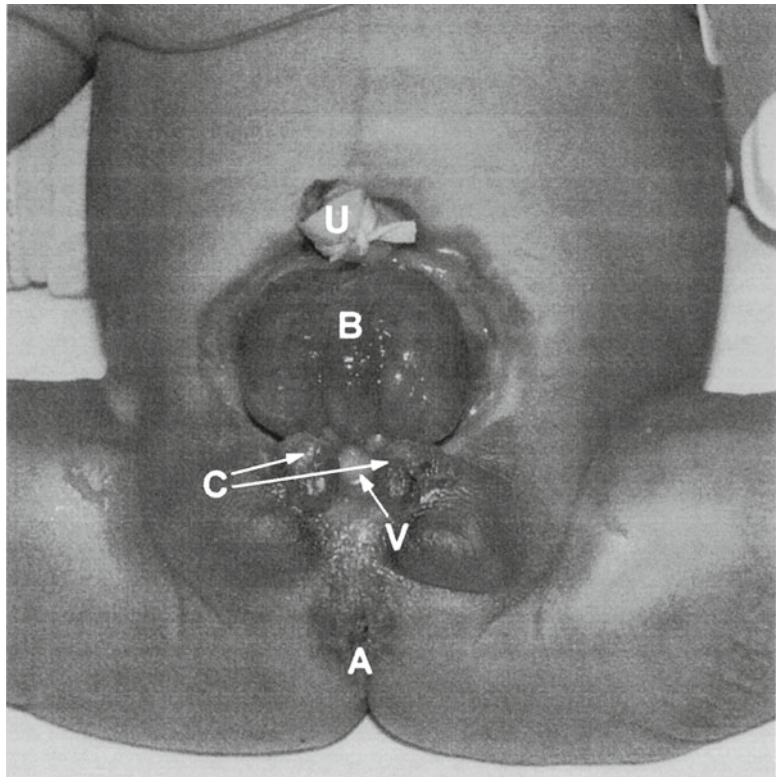

Fig. 22.1 Female neonate with bladder exstrophy. *B* exstrophic bladder, *C* clitoral bodies, *V* vagina, *U* umbilical cord, *A* anus

Classic exstrophy and epispadias share a low incidence of anomalies affecting organ systems other than the genitourinary tract and bony pelvis. In contrast, patients with cloacal exstrophy have associated anomalies more often than not [6, 7]. These anomalies can affect the upper urinary tract, intestines, skeletal system, and neurologic system. A possible reason for this is that the cloacal exstrophy defect occurs much earlier in development affecting subsequent development of related structures including the spine, kidneys, and hindgut (Table 22.1).

Incidence

Bladder exstrophy occurs at a rate of one per 10,000 live births to one per 50,000 live births [8, 9]. This anomaly has long been recognized to occur more commonly in males than females with a ratio of 2.3–4:1 reported in the literature [10, 11]. Cloacal exstrophy occurs even more rarely with an incidence of 1:200,000–400,000 live births [12].

Genetic factors involved in exstrophy remain incompletely defined. To date, 18 familial cases of bladder exstrophy have been reported, the most recent of which describes a mother and son with bladder exstrophy [13]. In 1984, a survey of pediatric urologists and surgeons, reported nine cases related to 2,500 index cases of bladder exstrophy; this same series also reported on cases of twins and noted discordance in both fraternal as well as identical twinships [14]. Furthermore, in a study population of greater than six million births with 208 reported cases of exstrophy, no case had a family history for this anomaly [15]. Current recommendations on counseling about risk of recurrence in a sibling of a patient with exstrophy cite an estimate of about 1 % and a 1:70 chance of

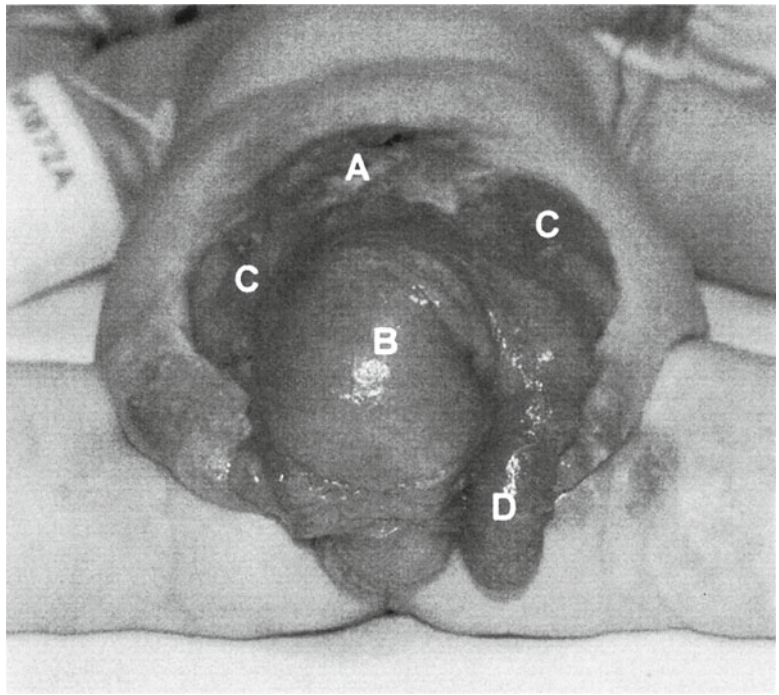

Fig. 22.2 Male neonate with cloacal exstrophy. (**a**) Small omphalocele status post treatment with silvadene, (**b**) hindgut plate, (**c**) exstrophic bladder halves, (**d**) intussuscepted ileum

transmission to the progeny of an affected parent [13]. Based on these findings, bladder exstrophy appears multifactorial rather than genetically based; environmental factors may play a significant role in the cause of the exstrophy–epispadias complex and a role for an epigenetic mechanism is possible.

Antenatal Diagnosis

Prenatal identification of exstrophy is possible although many cases remain undiagnosed until birth. The bladder may be visualized at 11–12 weeks gestation and the kidneys at 14–15 weeks; both become more obvious with advanced gestational age so that ultrasonography can reliably detect exstrophy before the 20th week of gestation [16–18]. Absence of the bladder is a hallmark of exstrophy but several findings also suggest the diagnosis. These include the presence of normal kidneys in association with a low-set umbilical cord. Sonographic examination may also reveal a semisolid mass protruding from the abdominal wall in addition to the above findings [19, 20]. Gearhart and coworkers reviewed the antenatal ultrasonographic studies of 25 women who delivered live infants with exstrophy. They noted the following:

- An absent bladder in 71 % of the studies
- A lower abdominal protrusion in 47 % of the studies
- An anteriorly displaced scrotum with a small phallus in 57 % of the male fetuses
- A low-set umbilical cord in 29 % of the studies
- An abnormal iliac crest widening in 18 % [18]

Since urine production is normal for these fetuses, amniotic fluid levels should be normal. Prenatal diagnosis allows optimal perinatal management of these infants including delivery near a pediatric center equipped to treat babies with this unusual anomaly. Many affected fetuses are still not detected antenatally [21]. In a review of 29 antenatal studies of 17 children born with exstrophy, only three were identified before delivery despite the presence of findings to suggest the

Table 22.1 Affected organ systems in the exstrophy–epispadias anomalies

Deformation	Cloacal exstrophy	Cloacal exstrophy variant	Classic exstrophy	Epispadias
Exstropic bladder	+	+	+	(–)
Open bladder neck	+	±	+	±
Reflux	+	±	+	±
Genitalia				
Epispadias	+ (severe)	±	+	+ (can be minor)
Failure of Müllerian duct function	++	+	(–)	(–)
Pelvis				
Lack of pelvic floor support	++	+>++	+	(–)
Pubis symphysis diastasis	++	+>++	+	+
Renal				
Ectopia	++	+	(–)	(–)
Dysplasia	+	+	(–)	(–)
Spine				
Vertebral	++	+	(–)	(–)
Lipomeningocele	+	+	(–)	(–)
Meningomyelocele	Rare	Rare	Rare	(–)
Abdominal wall				
Omphalocele	++	++	(–)	(–)
Intestine				
Short bowel absent large bowel	++	±	(–)	(–)
Imperforate anus	++	++	(–)	(–)
Neurology				
Paraplegia	±	±	(–)	(–)
Limb deformity	±	±	(–)	(–)

diagnosis [18]. Subtle findings such as low umbilical cord insertion and the location of the genitalia will only be seen if the fetus is examined in sagittal alignment with the spine. Because of the abnormal genitalia findings, the diagnosis is easier to make in males than females. Iliac crest widening can also be seen during the routine prenatal evaluation of the lumbosacral spine that is performed to evaluate for myelomeningocele. The iliac angle will be about 110° rather than the 90° that is normally seen [22].

Antenatal diagnosis of cloacal exstrophy is also possible. Austin reported the typical findings associated with cloacal exstrophy in utero. These include:

- Nonvisualization of the bladder
- A large midline infraumbilical anterior wall defect
- Omphalocele
- Myelomeningocele
- Widened pubic arches
- Lower extremity defects
- Renal anomalies [23]

In a review of 22 patients with cloacal exstrophy, all or some of these findings could be identified antenatally for 19 patients.

Antenatal diagnosis has many benefits. It allows the expectant parents the opportunity to anticipate and plan for a child who will have significant anomalies at birth. The early counseling should include the expertise of a pediatric urologist experienced in the treatment of bladder exstrophy since the overall prognosis of these children is excellent if initially treated at medical centers with physicians deeply experienced in the treatment of this condition. Antenatal

identification also permits parents to have these children delivered at a tertiary medical center equipped to provide multidisciplinary consultation and services.

Because these congenital anomalies are rare, health care providers who lack insight and knowledge of this disorder may find themselves in the position of counseling prospective parents of these patients. The resultant counseling of these families by health care providers who are unaware of the true potential of patients with these birth defects can result in overly pessimistic assessments. This is unfortunate in view of the very satisfactory long-term outcome and life expectancy with appropriate management. Discussions regarding treatment options including therapeutic abortion should include pediatric surgeons and urologists familiar with the care of these children. Increasingly, effective resources and contacts are available online.

Preoperative Care

To prevent trauma to the exposed bladder plate after delivery, the umbilical cord should be ligated with silk suture rather than a plastic or metal clamp. The exstrophic bladder should be protected against the elements by whatever means are available. We prefer a hydrated gel dressing such as Vigilon^{R}. This type of dressing protects the bladder plate and stays in place to allow handling of the infant with minimal risk of trauma to the bladder. We have used this dressing for over 2 months for infants who could not undergo immediate repair due to severe prematurity and found minimal inflammation of the bladder at the time of total primary repair. The exposed bladder may be covered with plastic wrap as an acceptable alternative. Either dressing should be replaced daily. The bladder should be irrigated with normal saline with each diaper change. Other authors have advocated the use of a humidified air incubator with no dressing at all to minimize bladder trauma [24].

Routine use of intravenous antibiotic therapy in the pre- and postoperative period decreases the chance for infection. These children should also undergo ultrasonography to assess the kidneys preoperatively and to establish a baseline examination for later ultrasonographic studies. A spinal sonographic examination should also be obtained if sacral dimpling or other signs of spina bifida occulta are noted on physical examination.

Preoperative care of children with cloacal exstrophy is more involved. Because the care of patients with cloacal exstrophy involves multiple organ systems, these patients are optimally cared for at a tertiary medical center. As a result of the advances in neonatal care and intravenous nutrition, the survival of neonates with cloacal exstrophy is quite high. Mortality in this time period is usually due to concomitant anomalies affecting the cardiovascular or pulmonary systems in these patients rather than directly as a result of the cloacal exstrophy. In the past mortality was high for these patients because of the poor nutritional and fluid support. With hyperalimentation and surgical sparing of the hindgut to preserve salt and water, the cloacal exstrophy patient has a good prognosis. The initial hospitalization may be significant, however. Preoperative studies include ultrasonography and karyotyping. Sonographic examination allows the evaluation of the upper urinary tracts, internal genital structures, and spinal cord. MRI may also evaluate spinal abnormalities. MRI of the pelvis is also useful to characterize the anatomy in the pelvis [25]. Because the genital anomalies associated with cloacal exstrophy may cause confusion in accurately identifying the sex of the baby, karyotyping is indicated to define the chromosomal sex. The decision to gender reassign is usually based on the assessment of reconstruction potential. This should only be done by a team very experienced in the care of the cloacal exstrophy patient. Antenatal imprinting may result in behavioral patterns that follow the genetic sex. This has resulted in sex conversion to the genetic sex in later years for some of these children who previously had been sex-reassigned.

Operative Intervention: Methods and Timing

Bladder Exstrophy

Despite the innumerable operations that have been applied to the treatment of exstrophy, operations for bladder exstrophy currently fall largely into two strategies. The first includes operations designed to remove the exstrophic bladder and replace it with a form of urinary diversion. The second includes reconstructive procedures designed to reconstruct the bladder either in multiple stages or in a single stage. Surgeon preference, patient anatomy, previous surgical procedures, availability of tertiary care facilities, and access to medical care all play a role in which operative procedures are chosen. No standard of care exists for this patient population. However, because of the complexity of exstrophy, specialists with an interest in the exstrophy–epispadias complex best manage these patients by tailoring their care to each patient's situation.

As currently described, the staged approach to bladder exstrophy reconstruction includes the following steps:

1. Initial bladder closure—ideally in the newborn period
2. Epispadias repair—usually performed at 12–18 months of age but may be combined with initial bladder closure, especially if initial bladder closure is delayed beyond 6 months of age
3. Bladder neck reconstruction—usually performed at 4–5 years of age or when age appropriate for toilet training and bladder capacity adequate

Mitchell, Kelley, and others have repopularized an integrated approach to the functional reconstruction of exstrophy. The goals of this approach include bladder closure, optimization of urinary continence, and correction of epispadias in a single operative procedure. Single stage reconstruction of the exstrophied bladder is best done in the newborn period for several reasons. The procedure is technically easier in the newborn period than when done in an older child. It also offers theoretical advantages as it may maximize the opportunity for normal bladder development and the potential for urinary continence. The delayed use of the total disassembly technique with primary reconstruction (Mitchell technique or CPRE technique) in older children with untreated exstrophy has been shown to be less successful than when used in the newborn period [3]. The bony pelvis also remains pliable in the newborn period so that osteotomies may be avoided in some cases—usually if closure can be performed within the first 72 h of life.

Several investigators have advocated for the use of delayed primary closure especially in regard to the use of the complete primary repair technique for exstrophy. They contend it is safer for the child, allows a more coordinated surgical effort, and more time for planning for the most expert team of clinicians to be available to provide surgical care [26]. Others have shown it is feasible to wait months after birth before repair [27]. Zaccara and coworkers used the delay to stimulate the penis with testosterone with the goal to reduce the chance of glans injury and reported good short-term outcomes with this approach in six patients [28]. The successful use of a delayed closure is predicated on adequate protection of the exposed vesical tissue while waiting to coordinate the primary repair. In a series from Mansoura, Hafez showed that delayed use of the primary complete repair technique is also possible in late or initial failed exstrophy closures but the success rates were less than with a primary repair in the newborn period [3]. A delayed repair does have its disadvantages. Nelson and Gearhart have shown an increased cost with immediate newborn closure costing roughly 2/3 that of a delayed repair at their institution [29]. Long-term results of a patient group that has undergone delayed repair in this fashion will take years to mature.

In the newborn period, we perform primary exstrophy closure using general inhalation anesthesia. We advise against the use of nitrous oxide during primary closure since it may cause bowel distension, which decreases surgical exposure during the operation and increases the risk of wound dehiscence. Some authors advocate the use of nasogastric tube drainage to decrease

abdominal distension in the postoperative period [30]. We do not use nasogastric suction in most patients, but routinely use a one-time caudal block to reduce the inhaled anesthetic requirement during the procedure.

For patients older than 3 days, or newborns with a wide pubic diastasis, pelvic osteotomy will facilitate closure and strengthen the anterior pelvic support which may potentiate later urinary continence [31, 32].

Children with epispadias can be managed operatively in a similar fashion to that described for bladder exstrophy.

Cloacal Exstrophy

Management of the genitourinary system for patients with cloacal exstrophy remains challenging. Many factors impact the surgical approach to these patients including the severity of the underlying anatomic anomalies, availability of tertiary care facilities, surgeon experience with cloacal exstrophy, and the effects of previous surgical procedures. A specific standard of care does not exist for this patient population. Because of the complexity of exstrophy, specialists with an interest in the exstrophy–epispadias complex should manage these patients so that their care may be optimized.

As with the management of classic bladder exstrophy, physicians caring for these patients approach the surgical management of the lower urinary tract of these patients with a strategy of functional reconstruction or urinary diversion. Urinary diversion involves excision of the exstrophic bladder plates and creation of a urinary reservoir from the gastrointestinal system. Functional reconstruction of the urinary tract may proceed in a staged or single stage approach depending on the physician team responsible for care and patient anatomy.

Postoperative Considerations

After a primary reconstructive procedure for exstrophy, the patient must be immobilized to decrease lateral stresses on the closure. A spica cast for 3 weeks to prevent external hip rotation and optimize pubic apposition can facilitate early discharge and home care. Modified Buck's traction has been used by many groups for a period of 3–4 weeks. A posterior lightweight splint can be used in newborns when the child is out of traction to facilitate home care and early removal of traction. Over the years we have tended not to use Buck's traction to facilitate earlier discharge and ease of care. External fixation devices have also been advocated by several centers. Fixator pins for these devices should be cleaned several times a day to reduce the chance for infection. Internal fixation may be necessary in older patients.

Because of the high incidence of vesico-ureteral reflux, we prescribe low-dose suppressive antibiotic therapy for all newborns after bladder closure. This is continued until vesico-ureteral reflux is corrected or is proven to resolve spontaneously. Postoperative factors that appear to directly impact the success of initial closure include:

- Postoperative immobilization
- Use of postoperative antibiotics
- Ureteral stenting catheters
- Adequate postoperative pain management
- Avoidance of abdominal distension
- Adequate nutritional support
- Secure fixation of urinary drainage catheters [33, 34]

Conclusions

Exstrophy remains one of the most challenging congenital anomalies in Urology. Children born with the exstrophy–epispadias complex are routinely treated early in life. Early treatment appears to increase the success of surgical intervention and reduce the morbidity associated with treatment.

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Disorders of Sex Development

23

Patricia Y. Fechner and Margarett Shnorhavorian

Introduction

The term *ambiguous genitalia* includes many different developmental abnormalities of the external sexual structures. Any infant in whom there is discordance between the appearance of the external genitalia and the karyotype may be considered to have ambiguous genitalia or a disorder of sex development (DSD) condition. DSD is defined as a congenital condition associated with atypical chromosomal, gonadal, or anatomical sex [1]. Reported incidence of these conditions varies widely depending on how broadly the term is defined. However, an incidence of one in 4,500–5,000 is frequently used in the literature [2]. DSD, formerly known as *intersex*, conditions may be the result of a variety of underlying causes. The Chicago Consensus statement on management of intersex disorders set forth new nomenclature to avoid the use of diagnoses which have been perceived by some to be pejorative (Table 23.1) [1]. Table 23.2 demonstrates the use of this classification [1]. Figure 23.1 is an example of a 46,XX female who was exposed to high levels of in utero androgens and appears to have virilized genitalia; an XY infant may exhibit an external appearance of female genitalia.

Evaluation

DSD are considered urgent urological conditions to evaluate and treat, for both medical and social reasons. Particular care must be made to identify those patients with endocrinological abnormalities that can be rapidly life threatening, such as certain forms of congenital adrenal hyperplasia (CAH) that are salt wasting. Evaluation of serum chemistries should be performed if there is a suspicion of such abnormalities. All states and many countries have instituted screening programs that include the assessment of 17-hydroxyprogesterone, a serum steroid precursor used in the evaluation of 21-hydroxylase deficiency, the most common form of CAH.

Evaluation and management of ambiguous genitalia is challenging. It is important for health care providers to be sensitive to the medical and social challenges in these situations, when the baby's gender may not be obvious. It remains a truism that one of the first questions a family is asked after a child's birth relates to determining the sex of the child. As a consequence, health care providers should discuss this issue thoughtfully with parents when their child is born with genital ambiguity. Typically, parents are told that their child has a birth defect that has interfered

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Table 23.1 New nomenclature set forth by the Chicago Consensus statement on management of intersex disorders

Previous	Proposed
Intersex	Disorders of sex development (DSD)
Male pseudohermaphrodite Undervirilization of an XY male Undermasculinization of an XY male	46,XY DSD
Female pseudohermaphrodite Overvirilization of an XX female Masculinization of an XX female	46,XX DSD
True hermaphrodite	Ovotesticular DSD
XX male or XX sex reversal	46,XX testicular DSD
XY sex reversal	46,XY complete gonadal dysgenesis

From Hughes et al. [1]; with permission from BMJ Publishing Group Ltd.

Table 23.2 An example of a DSD classification

Sex chromosome DSD	46,XY DSD	46,XX DSD
(A) 45,X (Turner syndrome and variants)	(A) Disorders of gonadal (testicular) development	(A) Disorders of gonadal (ovarian) development
	1. Complete gonadal dysgenesis (Swyer syndrome)	1. Ovotesticular DSD
		2. Testicular DSD (e.g., SRY+, dup SOX9)
(B) 47,XXY (Klinefelter syndrome and variants)	2. Partial gonadal dysgenesis	3. Gonadal dysgenesis
	3. Gonadal regression	
	4. Ovotesticular DSD	
(C) 45,X/46,XY (mixed gonadal dysgenesis, ovotesticular DSD)	(B) Disorders in androgen synthesis or action	(B) Androgen excess
	1. Androgen biosynthesis defect (e.g., 17-hydroxysteroid dehydrogenase deficiency, 5α reductase deficiency, StAR mutations)	1. Fetal (e.g., 21-hydroxylase deficiency, 11-hydroxylase deficiency)
		2. Fetoplacental (aromatase deficiency, POR)
(D) 46,XX/46,XY (chimeric, ovotesticular DSD)	2. Defect in androgen action (e.g., CAIS, PAIS)	3. Maternal (luteoma, exogenous, etc.)
	3. LH receptor defects (e.g., Leydig cell hypoplasia, aplasia)	
	4. Disorders of AMH and AMH receptor (persistent mullerian duct syndrome)	
	(C) Other	(C) Other
	(e.g., severe hypospadias, cloacal exstrophy)	(e.g., cloacal exstrophy, vaginal atresia, MURCS, other syndromes)

From Hughes et al. [1]; with permission from BMJ Publishing Group Ltd.
While consideration of karyotype is useful for classification, unnecessary reference to karyotype should be avoided; ideally, a system based on descriptive terms (for example, androgen insensitivity syndrome) should be used wherever possible
AMH anti-mullerian hormone; *CAIS* complete androgen insensitivity syndrome; *DSD* disorders of sex development; *MURCS* mullerian, renal, cervicothoracic somite abnormalities; *PAIS* partial androgen insensitivity syndrome; *POR* cytochrome P450 oxidoreductase

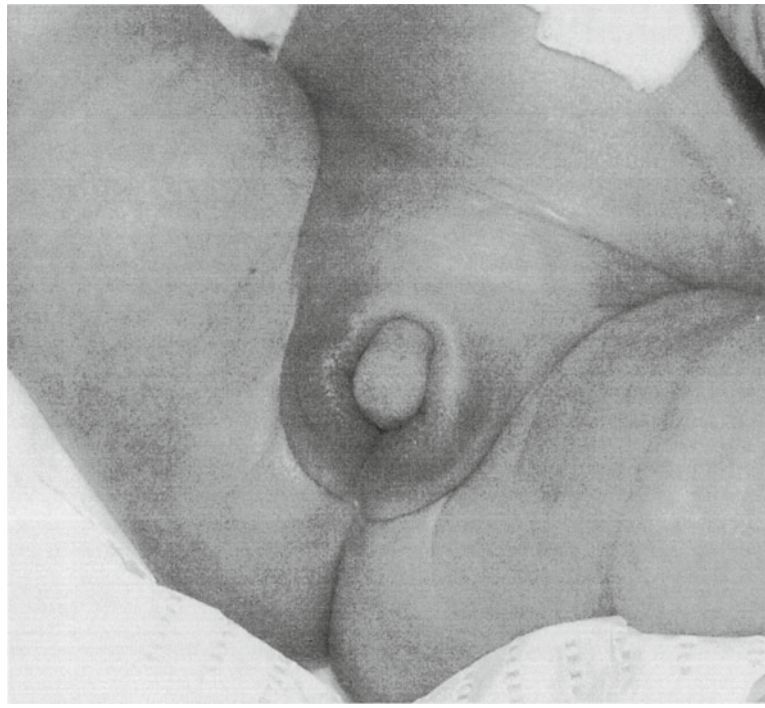

Fig. 23.1 External genitalia in karyotypic (XX) baby girl with congenital adrenal hyperplasia

with the usual way of determining the sex of their infant. Medical terminology may be confusing for many parents, and the situation may feel overwhelming for them.

The initial medical evaluation and treatment are focused on an evaluation of the underlying condition and a determination of the most appropriate gender of rearing for the infant. In some medical centers, a DSD team exists that includes pediatric urology, pediatric endocrinology, genetics, psychiatry/psychology, gynecology (pediatric/adolescent/reproductive), and cytogenetics. These teams meet on a regular basis to discuss the evaluation and management of new and ongoing cases. At the Seattle Children's Hospital, a DSD team has been in existence for almost 30 years. In addition to the aforementioned specialties there is a genetic counselor, clinical nurse specialist, bioethicist, perinatologist, and a liaison with local support groups and national advocacy groups. Determination of the underlying cause of the DSD may take longer than gender assignment and in some cases is never completely determined. When possible, identification of the underlying cause will permit more effective therapeutic interventions and counseling regarding the underlying inheritance patterns.

Initial discussions with the families of infants with DSD often set the tone for future interactions. Health care providers should be sensitive to the family's need to have information repeated. Often, a discussion of genital development and embryology is helpful to parents to understand how the precursor structures in a fetus may become phenotypically male or female depending on genetic and hormonal influences. To increase parental understanding, line drawings and diagrams are often useful, as are a review of the baby's physical examination findings. Online resources are available and include the Hospital for Sick Children's website (http://www.aboutkidshealth.ca/En/HowTheBodyWorks/SexDevelopmentAnOverview/Pages/default.aspx) which provides animation of male and female internal and external sex development. Ideally, family members should become familiar and

comfortable enough with the underlying condition that they can actively participate in the shared decision-making process regarding gender of rearing.

Diagnosis

History

A careful history may offer clues to the underlying diagnosis. Maternal aunts who are infertile or maternal uncles who are undervirilized may suggest a familial X-linked disorder such as some forms of androgen insensitivity syndrome. A family history of unexplained neonatal death suggests CAH. Maternal exposure to exogenous or endogenous androgens, progesterones, or estrogens should also be investigated.

Physical Examination

A detailed physical examination of the newborn genitalia is essential. Key components of the exam include the following:

- Symmetry of the external genitalia
- Presence and location of palpable gonads
- Extent of virilization
- Presence of additional anomalies

The most important part of the examination is palpation for the presence or absence of gonads in the labioscrotal folds. A gonad that has descended into the labioscrotal folds is typically a testis, and the patient usually has a 46,XY karyotype, although there are exceptions (e.g., SRY+ XX testicular DSD, ovotesticular DSD and hernia uterine inguinalae). In the absence of palpable gonads in an otherwise phenotypic male, no definitive gender assignment should be made until further evaluations are performed, including a stat karyotype for the presence of a Y chromosome, hormonal studies, and radiographic studies.

Additional findings to be noted on physical exam include phallus size, location of urethral opening, appearance and pigmentation of labioscrotal folds, and associated anomalies. Observing the baby urinate may also be necessary to locate the position of the urethral meatus. The extent of external virilization may be documented using the Prader classification system (Table 23.3). A more complete description of the extent of external virilization and internal structures are the external masculinization score (EMS) and the internal masculinization score (IMS) (Table 23.4) [3]. Other physical findings to note include phallic configuration, length and diameter, including the glans, and the extent of fusion of the labioscrotal folds.

Table 23.3 Prader classification

Prader classification	Features
I	Hypertrophic clitoris with otherwise normal external female genitalia
II	Hypertrophic clitoris with urogenital sinus
III	Hypertrophic clitoris, narrow and deep urogenital sinus, high urethrovaginal confluence
IV	Phallus with small urogenital opening
V	Normal external male genitalia

Imaging Studies

Ultrasonography can be a useful imaging modality to identify internal gonads, although pelvic ultrasonography is not generally considered sensitive enough to confirm their absence if gonads are not visualized [4]. Pelvic ultrasonography can also document the presence of uterine structures in an externally virilized female. It is most helpful to perform this study immediately after birth when the maternal estrogen effect increases the thickness of the endometrial lining of the infant uterus. After the maternal estrogen effect decreases, the uterus becomes significantly more difficult to visualize.

Magnetic resonance imaging with intravenous gadolinium or laparoscopic exploration of the pelvis are the most accurate methods to evaluate pelvic anatomy in this population and should be used when indicated [5].

Table 23.4 Masculinization score

Feature	Score for yes/no or condition
EMS	
Scrotal fusion	3/0
Micropenis	0/3
Urethral meatus	
Normal	3
Glandular	2
Penile	1
Perineal	0
Right and left gonad (score for each)	
Scrotal	1.5
Inguinal	1
Abdominal	0.5
Absent	0
IMS	
Uterus	0/3
Fallopian tube (right and left score each)	0/2
Epididymis (right and left score each)	2/0
Vas deferens (right and left score each)	2/0

From Ahmed et al. [3]; with permission from John Wiley and Sons

The masculinization score based on points allocated to a variety of anatomical features. The EMS is based on external genital features and the IMS on internal sexual organs

Improved magnetic resonance imaging technology makes this an increasingly attractive imaging modality to evaluate these children, although some children require deep sedation or general anesthesia to obtain an adequate study if they cannot hold still. Before reconstructive surgery, retrograde fluoroscopic studies of the introitus can be particularly helpful to assess the extent of urethrovaginal fusion and the length of the urogenital sinus (Fig. 23.2). Retrograde studies may also provide more anatomic information by outlining the vagina, cervical impression, and uterus.

Karyotyping

Genetic evaluation by karyotype should be performed as soon as possible, even if prenatal chromosome testing was previously performed. A stat karyotype for sex chromosomes can usually be obtained within 24–48 h. In addition fluorescent in situ hybridization (FISH) for SRY, the sex-determining region of the Y chromosome, should be obtained. Usually, peripheral blood karyotypes are adequate unless the patient has a mosaic karyotype with another cell line restricted to gonadal tissue [6]. In this case, a gonadal biopsy may be necessary to confirm the karyotype.

Laboratory Studies

Babies born with ambiguous genitalia should undergo a metabolic evaluation, including serum electrolytes (both after birth and several days later if CAH is a possibility). Laboratory studies of serum testosterone, dihydrotestosterone, follicular stimulating hormone, luteinizing hormone, estrogen, Mullerian inhibiting substance (MIS), and inhibin B will help determine gonadal function and the integrity of the hypothalamic–pituitary–gonadal axis. Other possible laboratory studies include serum 17-hydroxyprogesterone and androstenedione. Levels of these hormones are elevated in the serum of infants with the most common form of CAH, 21-hydroxylase deficiency. MIS and inhibin B may be useful in select cases if karyotyping shows an XY pattern, but the infant has nonpalpable gonads [7].

The first 3 months of life in a male infant provide a unique opportunity to evaluate the pituitary–gonadal axis. Male infants have a "mini-puberty" which allows one to evaluate gonadal function without any external hormonal stimulation [8].

Outside of this timeframe, to adequately assess the potential for testosterone production for some of these children, human chorionic gonadotropin (hCG) may be administered and the subsequent hormonal response measured. Several different protocols have been described. They involve daily or weekly hCG injection for several weeks [9]. hCG injections are useful to assess not only the potential for testosterone production, but also to target tissue response to testosterone if it is made [9].

Molecular genotype analysis is commercially available and is extremely valuable in the evaluation

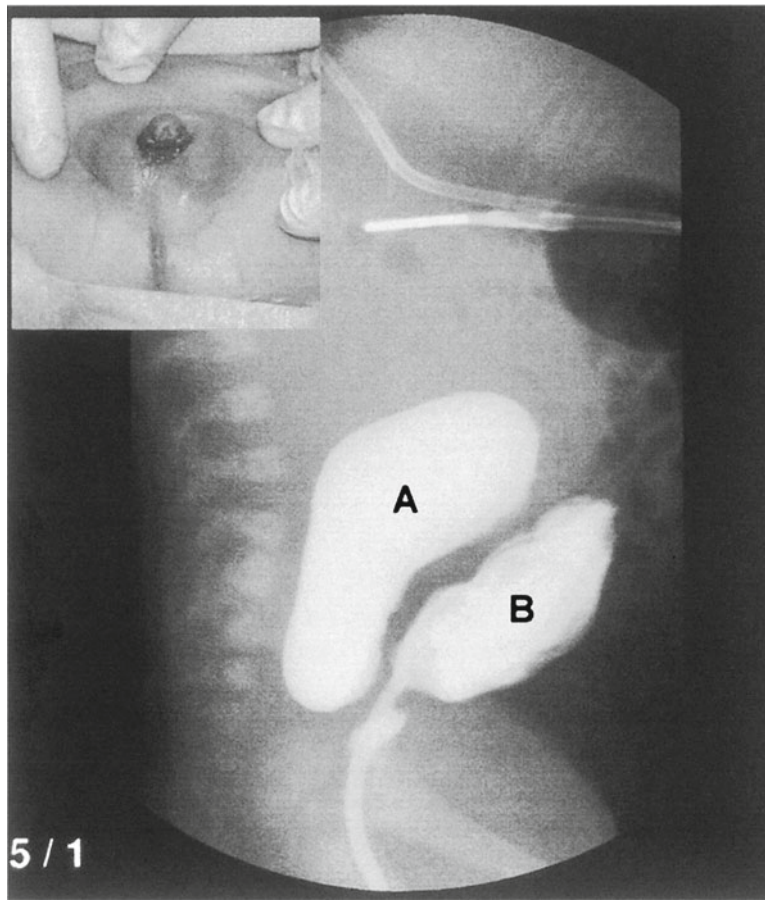

Fig. 23.2 Female neonate born with a cloacal anomaly. Retrograde fluoroscopic study demonstrating the (**a**) vagina and (**b**) bladder. Inset photo demonstrates single perineal opening

of some DSD. Gene Reviews (http://www.genetests.org) is a site developed at the University of Washington that has extensive reviews on genetic disorders and provides information on which laboratories provide genetic testing, both for commercial use and for research. Examples of genes which can be analyzed include: SRY, SRD5A2 (5α reductase deficiency), and the androgen receptor.

Management

Careful communication with the family via a DSD multidisciplinary team is essential in cases of ambiguous genitalia. It is vitally important to avoid definitive gender assignment until data are collected and interpreted and discussions are held between the DSD team and the family. Gender-specific pronouns are typically avoided when speaking to the family about the infant until the family and the DSD team make a decision regarding the gender of rearing. A focused effort to obtain these studies and engage in these discussions in a timely fashion is important not only to assist the family in coping with the social stress of having a child with gender ambiguity but also to ensure that potentially life-threatening conditions, such as CAH, are recognized early.

The primary decision in the management of these patients focuses on the gender of rearing. This decision is based on several factors, including

the genetic diagnosis, specific pathophysiology, the chance for spontaneous pubertal development, the anticipated capacity for satisfactory sexual intercourse and orgasm, fertility potential, and risk for gonadal tumors, such as gonadoblastoma, when Y chromosomal material is present in a dysgenetic gonad [10]. Hormonal stimulation with hCG or testosterone may be helpful to assess the potential for virilization in some DSD cases.

Each child must be considered individually when making gender assessment decisions. Few long-term studies exist regarding the function and quality of life of patients born with DSD [11]. However, renewed interest in open, honest communication with the families and children born with these conditions may help provide answers to some of these questions in the future [10]. Consultation with specialists to plan for the appropriate medical and surgical management ideally involves pediatric endocrinologists, pediatric urologists, and psychiatry or psychology services along with a medical genetics and cytogenetics team.

In specific conditions, medical therapy is required. Patients diagnosed with CAH require glucocorticoid therapy to suppress excessive adrenal androgen secretion and prevent adrenal crisis. All infants require mineralocorticoids if they have a salt-losing form of CAH and many with simple virilizing, non-salt wasting also require mineralocorticoids. In addition, many infants will require additional salt supplementation in the form of NaCl. Typically, oral cortisol is used for glucocorticoid replacement, and oral fludrocortisone (9α-fluorohydrocortisone) is used for mineralocorticoid replacement. Long-term hormonal management is necessary.

Timing and extent of surgical correction for ambiguous genitalia remain controversial. It is important to inform families fully about the complex psychosocial issues related to surgical correction in addition to the medical risks and benefits. Labioscrotal reduction may be beneficial for some virilized female patients. Phallic reconstructive surgery may also be important to create a cosmetically acceptable end function for those patients with DSD who are undervirilized and have been assigned a male gender status. Issues of timing of surgery currently focus on the benefits of achieving true informed consent by waiting until patients are old enough to decide for themselves vs. the disadvantage of longer recovery times and potentially poorer surgical outcomes compared to when these operations are done in early childhood.

The ultimate success for an infant with ambiguous genitalia may depend as much on the quality and extent of psychosocial support as on sophisticated medical and surgical management. In recognition of this, many DSD teams fully integrate psychiatric services into the management of these patients and their families.

Complex family dynamics will also have a profound impact on children born with ambiguous genitalia. Honest and informed communication between the family and the health care team is important to create trust and understanding with this emotionally charged issue.

Follow-up

The generalist must play a central role during follow-up care for the infant with ambiguous genitalia because a large number of consulting services are typically involved, including medical genetics, endocrinology, urology, and psychiatry. Long-term psychosocial support for the family and the child should be provided. Patient-based support groups are an excellent resource for both the children and families. For those patients requiring ongoing medical management for hormonal replacement, a primary care physician will also need to be an active participant.

Summary

The evaluation and management of children with DSD remains challenging medically and socially. Despite technological advances, and improved medical understanding of the causes of DSD, no absolute answers exist in the care of these patients and their families. It is important for health care providers to be sensitive to the

medical and social challenges in these situations and remain up-to-date on the current body of knowledge in this field.

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Posterior Urethral Valves

24

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Introduction

Posterior urethral valves (PUVs), membranes located in the prostatic urethra, act as one-way valves impairing the antegrade flow of urine from the bladder and upper urinary tract. They are the most common forms of congenital urethral obstruction, with an incidence of 1 in 5,000–8,000 live male births [1]. Boys with PUVs present with a wide spectrum of symptoms, from minor voiding dysfunction to end-stage renal disease (ESRD) and even death. Proper initial treatment and long-term management are essential to maintain good bladder and renal function.

Anatomy and Pathophysiology

Although not the first to identify PUVs, Young et al. in 1919 were the first to publish a detailed anatomic description of PUVs based on their observations in a small number of cases [2]. According to Young's classification, type I valves originate from the urethral crest of the distal verumontanum and fan across the urethral lumen to fuse anteriorly. Type II valves originate at the verumontanum and pass along the posterior urethral wall toward the bladder neck. It was subsequently recognized that these are not obstructive, but are hypertrophied muscle fibers of the superficial trigone. The type III valve is an annular membrane that originates distal to the verumontanum near the bulbomembranous junction and spans transversely across the urethra.

It has been suggested that the Young's classification of PUVs may be incorrect since the subjects had previously been instrumented. Modern endoscopic studies [3] suggest that all patients with PUVs have the same diaphragmatic configuration, which is iatrogenically altered by urethral instrumentation.

The etiology of PUVs remains unknown. It was thought for a long time that PUVs were developmental anomalies. Recent studies have suggested an embryologic etiology. By the eighth week of gestation, the prostatic urethra develops from the urogenital sinus. The distal segments of the mesonephric and paramesonephric ducts are absorbed into this region to form the ejaculatory ducts and the prostatic utricle, respectively. As a result of the expanding ejaculatory ducts and prostatic utricle, the verumontanum forms on the floor of the prostatic urethra. During this process, the mesonephric ducts move from an anterolateral position to a posterior one. The normal male

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urethra contains folds called plicae colliculi that are believed to come from the absorption of the mesonephric ducts into the urethra. It is hypothesized that aberrant movement of the mesonephric ducts into the urethral wall results in PUVs instead of the normal plicae colliculi [4]. Research demonstrates that PUVs have occurred in siblings, twins, and successive generations, suggesting a polygenetic pattern of inheritance [4–6].

PUVs have a wide range of effects on the urinary tract depending on the severity of urethral obstruction. The nature of injury appears to be caused by high-pressure storage and inadequate drainage of urine, producing characteristic changes to the urinary tract. In response to the high voiding pressures, the prostatic urethra dilates and elongates, in some cases to a volume equivalent to that of the bladder. Histological studies of bladders from fetuses with PUVs demonstrate hypertrophy and hyperplasia of detrusor smooth muscle and increased connective tissue [7]. Similarly, the muscle of the bladder neck is hypertrophied and rigid. Despite these changes, the bladder neck does not cause further obstruction, and these changes usually resolve with ablation of the valves [8].

High-pressure bladder filling and voiding lead to poor drainage of urine from the upper tracts which, in turn, result in ureterectasis and pelviectasis. Ureterectasis compromises peristalsis and drainage of urine from the upper tract. Variation in competency of the vesicoureteral junctions may direct the high pressures generated by the bladder to one kidney, sparing the other from the damaging effects of obstruction, so-called valves, unilateral reflux, and dysplasia (VURD) syndrome [9, 10]. This is one example of a pop-off mechanism which protects one kidney from the high pressures generated in the bladder. Other pop-off mechanisms include forniceal rupture which leads to urinary ascites and urinomas, and bladder diverticulum which may protect one or both kidneys. Urinomas are present in 1–15 % of patients with PUVs. Conflicting studies debate whether the presence of urinomas can truly be considered pop-offs that protect the kidneys and preserve long-term kidney function [11, 12].

The renal damage induced by PUVs is caused by renal dysplasia and obstructive uropathy. In almost all patients with PUVs, there is some degree of renal dysplasia, characterized by disorganization of renal parenchyma and the presence of embryonic tubules, cartilage, cysts, and mesenchymal connective tissue (Fig. 24.1). Some studies suggest that high bladder pressures interfere with the normal differentiation of metanephric mesenchyme resulting in renal dysplasia [13, 14]. Other studies propose that renal dysplasia is caused by an abnormal position of the ureteral bud along the mesonephric duct [15]. This theory may be supported by the increased rates of undescended testicles seen in boys with PUVs. In a study by Heikkila et al. [16] of 192 patients with PUVs, 16 % had unilateral or bilateral undescended testicle(s), a 16-fold increase from the general population. They also found that in patients with PUVs, the presence of undescended testicle correlated to worse renal function.

Regardless of the mechanisms, the renal dysplasia observed in patients with PUVs appears to be irreversible. However, in addition to their congenital renal dysplasia patients with PUVs also have a component of obstructive uropathy which is potentially reversible. Obstructive uropathy is characterized by glomerular and tubular dysfunction. Up to 60 % of valve patients have tubular dysfunction impairing their ability to concentrate and acidify the urine [17], causing a pathologically high urine output and electrolyte imbalances [18]. Additionally, the high urine output can create further dilation of the urinary tract, worsening the degree of hydronephrosis and bladder dysfunction [19].

Besides the urinary system, the effects of PUVs can be observed in the pulmonary system as a result of a reduction in amniotic fluid volume. Amniotic fluid volume is primarily dependent on urine production after the first trimester of gestation. Oligohydramnios resulting from inadequate fetal urine production interferes with the normal development of the lungs. The proposed mechanism for pulmonary hypoplasia includes physical restriction of fetal breathing movements, resulting in a small chest cavity and reduced chest wall motion [20, 21]. The lack of amniotic fluid reaching the lung buds results in

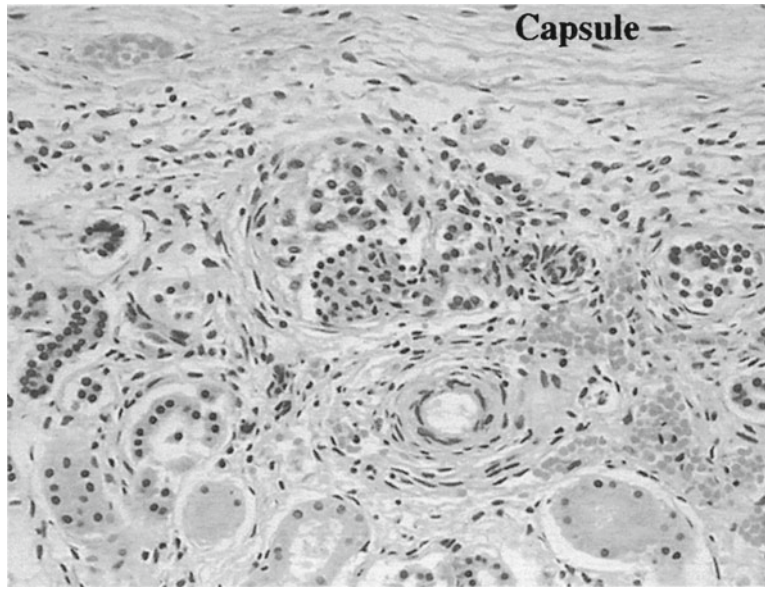

Fig. 24.1 Evidence of dysplasia from the kidney of a fetus at 24 weeks gestation with posterior urethral valves (PUVs) and severe oligohydramnios. Note the lack of nephrogenesis at the periphery and normal tubules

decreased branching of the bronchial tree and alveolar formation [22–24]. The degree of pulmonary hypoplasia varies depending on the severity of the PUVs and degree of oligohydramnios. In its most severe form, PUVs can result in anhydramnios and lead to Potter's sequence.

Clinical Presentation

Patients with PUVs may present with a wide spectrum of symptoms, from minor voiding dysfunction to death [25]. With the advent of routine maternal ultrasonography, the majority of patients with PUVs are diagnosed antenatally [26–28]. Characteristic findings on antenatal ultrasonography include a dilated/thickened bladder with a "keyhole sign" (elongated dilated posterior urethra inferior to the dilated bladder), oligohydramnios, and hydroureteronephrosis (Fig. 24.2). However, these findings have only a 40 % positive predictive value [29, 30]. In a retrospective study only the combination of bladder wall thickness with bladder dilatation was diagnostic for PUVs, with a high sensitivity and low specificity for the disorder [31]. Increased renal echogenicity on prenatal ultrasonography (US) suggests underlying renal pathology and may help to support a diagnosis of PUVs (Fig. 24.3) [32]. Additional prenatal findings in patients with PUVs may include cortical atrophy (renal cortex less than 2 mm thick) [33], cortical cysts, signs of fetal distress, and intrauterine growth restriction. Multivariate analysis has shown that oligohydramnios is predictive of the presence of obstruction [34]. However, prenatal US parameters such as amount of amniotic fluid and degree of renal hyperechogenicity have not been shown to predict future renal function [35].

Despite screening with prenatal US, a significant number of patients with PUVs are not prenatally diagnosed, especially when the maternal US is performed early in pregnancy. For those who are not diagnosed prenatally, newborns commonly present with an abdominal mass. Imaging will reveal the mass to be a dilated bladder, hydroureteronephrosis, and/or urinary ascites [36]. Older infants may present with urinary tract infections (UTIs), sepsis, or renal insufficiency [37]. Some children with PUVs do not present until much later, with UTI, gross hematuria, renal colic, or voiding complaints

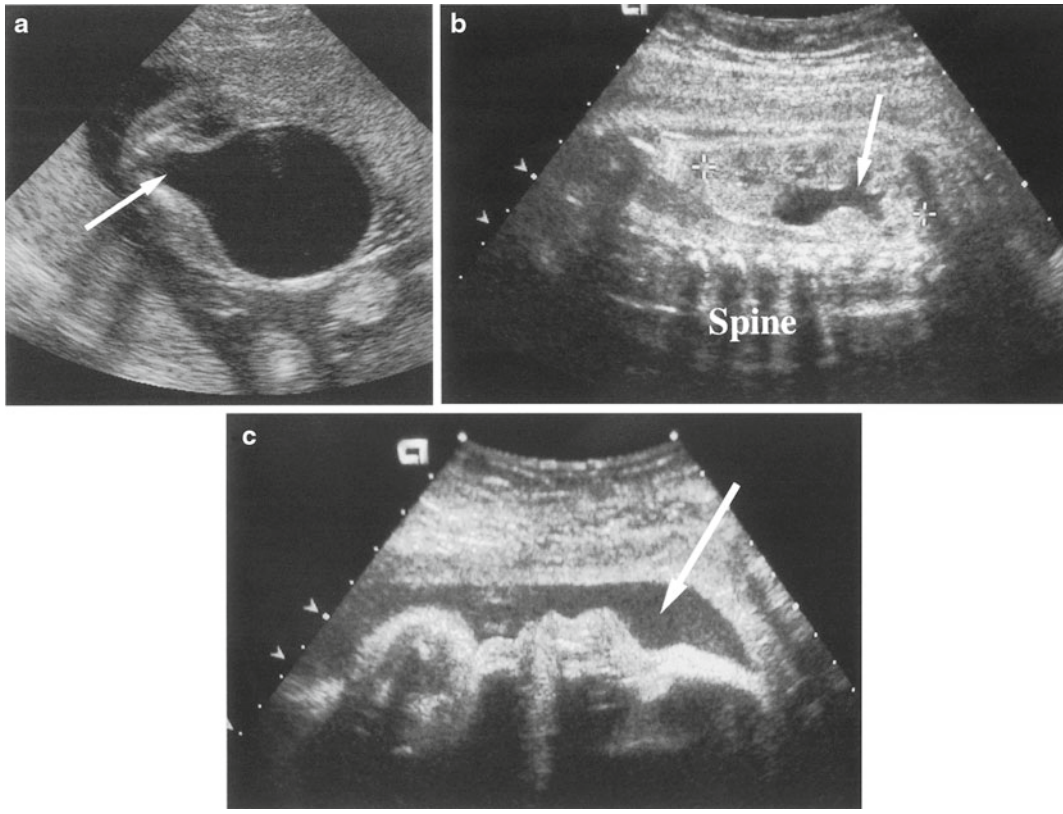

Fig. 24.2 Ultrasound of a fetus at 30 weeks gestation with PUVs. (**a**) Note the dilated bladder and posterior urethra (*arrow*). There is associated (**b**) hydronephrosis (*arrow*) and (**c**) oligohydramnios (*arrow*)

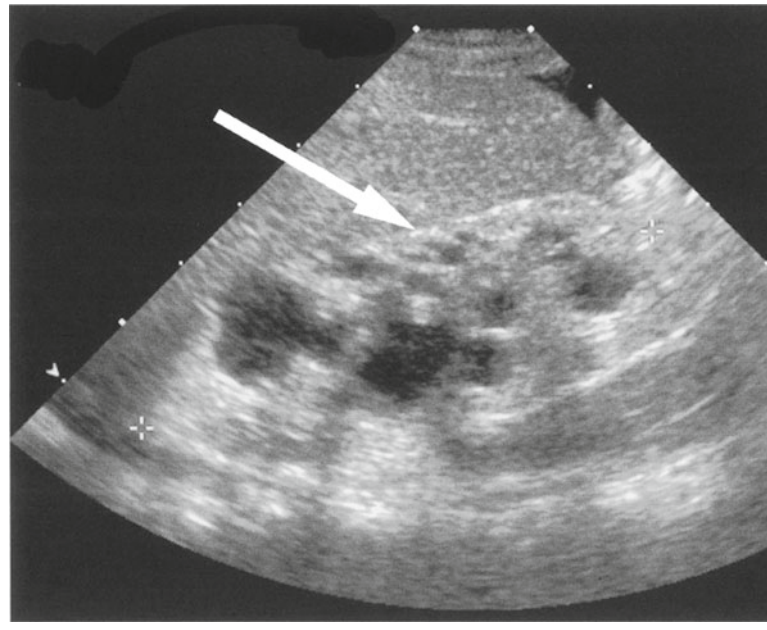

Fig. 24.3 Ultrasound of the right kidney in a 4-day-old infant with PUVs. Note the increased echogenicity compared to the liver and cysts in the periphery suggestive of renal dysplasia

such as urinary frequency, dribbling, or urinary incontinence [38]. There has been a great deal of research attempting to correlate age of presentation with PUVs and long-term outcomes. It was hypothesized that late presentation would correlate with less severe (and thus subclinical) disease. However, several case series' suggest that patients who present later in childhood have outcomes which are either the same, or, in fact, worse than those who present in infancy [10]. Regardless of age at presentation, patients need prompt treatment and close surveillance to optimize renal function.

Evaluation

All male infants with significant hydronephrosis previously diagnosed on prenatal ultrasound should be evaluated to rule out PUVs. In addition to PUVs, the differential diagnosis for these patients includes prune belly syndrome, bilateral ureteropelvic or ureterovesical junction obstruction, bilateral vesicoureteral reflux, congenital urethral atresia, and anterior urethral valves. A thorough radiological evaluation is necessary to make an accurate diagnosis.

Immediately postnatally, the neonate with suspected PUVs should be properly resuscitated as required. A multidisciplinary team of neonatologists, pediatric pulmonologists, urologists, and nurses should work together to deliver optimal care to these patients who have the potential to be critically ill. A radiographic diagnosis should be obtained first with a postnatal US. Because dehydration is common during the first 48 h of life, US studies performed before this time may underestimate the degree of hydronephrosis, and thus do not rule out obstruction [39]. In addition, a voiding cystourethrogram (VCUG) should be performed regardless of whether the patient is voiding normally and regardless of ultrasound results. The VCUG should be performed using a 5Fr pediatric feeding tube that has been confirmed to be properly positioned in the bladder. A catheter with a balloon is not recommended because the latter may obscure bladder anatomy and obstruct the ureteral orifices.

When performing a VCUG, cyclical filling and voiding should be done to distend the bladder and possibly the urethra and upper tracts. Inadequate distension or poor voiding may miss vesicoureteral reflux or dilation of the prostatic urethra (Fig. 24.4) [40]. Furthermore, the initial cycles of contrast may be diluted from the large volume of urine in the upper tracts preventing detection of vesicoureteral reflux. Vesicoureteral reflux is seen in approximately 50 % of the patients with PUVs [41, 42]. An oblique view of the urethra is essential to demonstrate an elongated and dilated prostatic urethra with an elevated bladder neck, which is commonly seen in patients with PUVs (Fig. 24.5).

Finally, a technetium-99m mercaptoacetyltriglycine (MAG-3) radionuclide renal scan may be useful in evaluating the renal function of patients with PUVs. This test is not recommended in neonates because of the relative immaturity of the newborn kidneys, which do not provide for proper concentrating of the radionuclide [43].

During resuscitation of the neonate with PUVs, laboratory evaluation of renal function and electrolytes should be obtained. The serum creatinine levels obtained in the first few days of life reflect the mothers' renal function due to the previously functioning placenta. Creatinine and urea nitrogen levels should fall to normal neonatal levels over the subsequent days as they begin to reflect the neonates' own renal function. Levels that rise (or do not fall as expected) may indicate poor kidney function. Monitoring electrolytes, weight, fluid intake, and output is essential in patients with PUVs.

Treatment

Once the diagnosis of PUVs is made, prompt relief of obstruction is imperative. In newborns with PUVs, a 5 or 6 Fr pediatric feeding tube without a balloon should be placed. Foley catheters may be used, but can be associated with poor upper tract drainage caused by occlusion of the ureteral orifices or irritation of the bladder by the balloon [44]. Furthermore, inadvertent inflation of the balloon in the dilated prostatic urethra can cause injury.

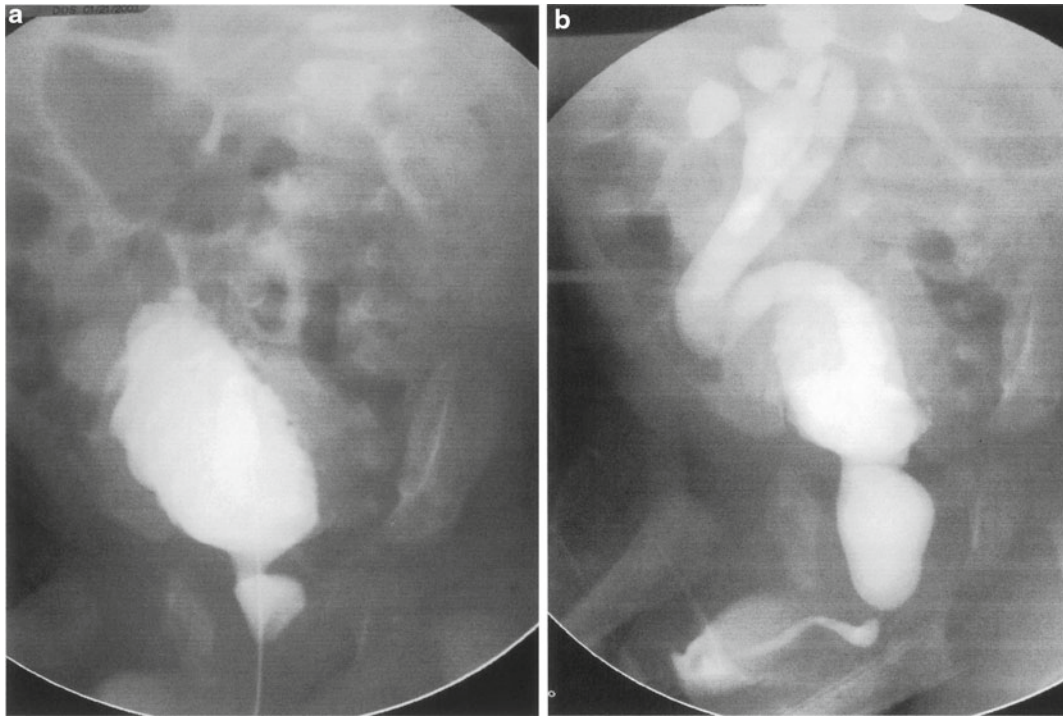

Fig. 24.4 (**a**) Voiding cystourethrogram (VCUG) performed with one filling cycle did not demonstrate any vesicoureteral reflux. (**b**) Cyclic VCUG demonstrated grade V reflux into the right kidney

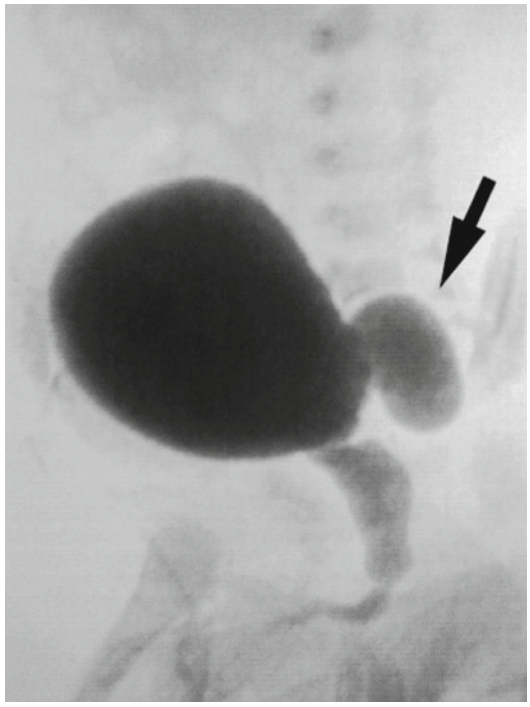

Fig. 24.5 Dilated posterior urethra with an elevated bladder neck can be seen in this oblique view of a VCUG. Note the presence of a bladder diverticulum (*arrow*), which can serve as a pressure pop-off mechanism

Because of the dilated, elongated posterior urethra and elevated bladder neck associated with PUVs, the catheter may be difficult to negotiate into the bladder, and catheters commonly will coil in the posterior urethra. A coudé tip catheter or one with a malleable guide may be used to assist in correct placement. Another technique is to guide the catheter through the prostatic urethra by pushing anteriorly against the posterior prostatic urethra using a finger in the rectum. This maneuver should straighten the dilated and elongated prostatic urethra providing a direct route for the catheter to enter the bladder. Proper placement should be confirmed by instilling irrigant into the catheter and aspirating the same volume, or with the use of radiographic studies such as cystography or an ultrasonography. Newborns with PUVs should be started on prophylactic antibiotics to prevent UTI especially if an indwelling catheter is placed.

After stabilization with catheter drainage, most infants can undergo endoscopic valve ablation. Historically, PUVs were ablated with open procedures which had a high risk of damaging the bladder and urethra [45]. With the development of newer technologies and small pediatric

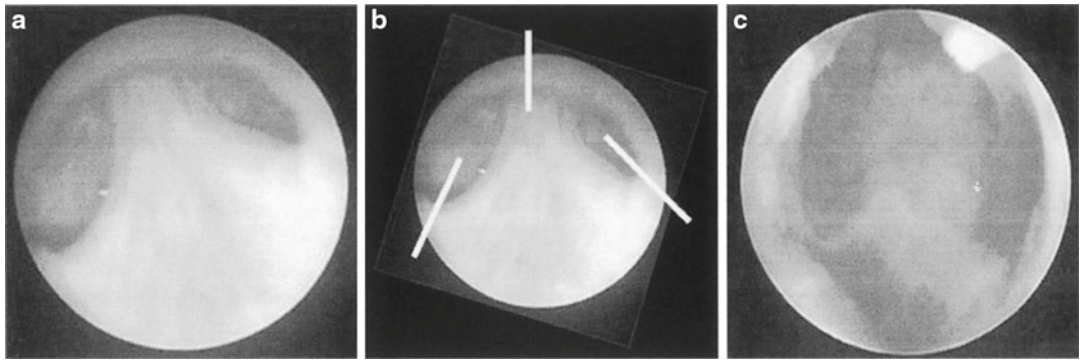

Fig. 24.6 Endoscopic view of posterior urethra (**a**) before and (**c**) after valve ablation. (**b**) Incisions are made in 4 and 8 o'clock positions; if needed, an incision can also be made at the 12 o'clock position

instrumentation equipment, most infants with PUVs can safely undergo endoscopic valve ablation.

In depth understanding of infant urethral anatomy and experience with the procedure is very important to good outcomes. There are three techniques currently in use for PUV ablation. In the standard approach, a 5Fr cystourethroscope or an 8.5Fr resectoscope is used to visualize the valves. A Bugbee electrode, hook, LASER, or cold knife is passed through the scope and used to incise the valves at the 5 and 7 o'clock positions. Incision at the 12 o'clock position may be necessary to completely open the urethral lumen (Fig. 24.6). Some authors have recommended not using electrocautery so as to prevent urethral sphincter injury or urethral stricture formation.

Low weight neonates (<2,500 g) are unable to undergo standard endoscopic valve ablation as the cystoscopes are either too small to allow the passage of working instruments or too large to pass through the urethra. However, a hybrid technique has been described by Soliman [46] for use in this cohort. This technique uses a neonatal cystoscope to visualize the placement of a 2 Fr Fogarty balloon past the valves. The balloon is then inflated and the balloon and scope are removed together. The technique's outcomes are comparable to other forms of cystoscopic valve ablation and can be used successfully in low weight neonates.

Alternatively, a Fogarty embolectomy balloon is placed past the valves under fluoroscopy. The balloon is inflated and then pulled out, which engages the valves with gentle, antegrade pressure and ablates them. This technique has comparable results to other endoscopic ablation techniques (97 % success) but requires radiation exposure for the patient [47]. Regardless of the technique employed, it is recommended that a catheter be left in place for at least 24 h. Some pediatric urologists do not use a post-ablation catheter.

Alternatives for initial treatment of infants with PUVs include vesicostomy and upper urinary tract diversion. For very small (<2,500 g), very sick, or premature neonates, a cutaneous vesicostomy may be performed, allowing valve ablation to be delayed until the patient is older. It appears to be safe with comparable long-term results to endoscopic treatment [48]. Vesicostomy may also be a good option in some valve patients with severe reflux, allowing improvement in the dilation of the upper urinary tract [49]. However, this procedure is also associated with a higher complication rate (up to 40 %), most commonly febrile UTIs [50].

Another option for treatment of PUVs is diversion above the level of the bladder with a cutaneous ureterostomy or pyelostomy. Although it is safe [51, 52], the efficacy of upper tract drainage compared endoscopic treatment or vesicostomy has not been clinically demonstrated. Additionally, patients who undergo upper urinary tract diversion will ultimately require reconstructive surgeries.

Most pediatric urologists recommend treating PUVs with endoscopic ablation, then monitoring degree of hydronephrosis and renal function. For those with decreasing hydronephrosis and creatinine levels no additional surgical procedure is required. Renal-bladder ultrasonography every 3 months for the first year should be obtained. If the

patient has vesicoureteral reflux prophylactic antibiotics are recommended. A post-ablation VCUG can confirm valve ablation and diagnose the presence or absence of vesicoureteral reflux. A vesicostomy should only be considered in those who cannot undergo valve surgery for technical reasons (significantly premature or small urethra) or for those with bladders that do not drain efficiently despite valve ablation. Upper tract diversion should only be considered in those patients with persistent severe hydronephrosis, creatinine levels greater than 2.0 mg/dL and poor bladder emptying demonstrated on VCUG. The need for upper tract diversion is uncommon for most patients with PUVs. Several studies suggest that all initial treatment options, whether primary valve ablation, vesicostomy, or upper tract diversion, are equally effective in optimizing renal function and somatic growth [51, 53].

Follow-Up Management

Long-term management of PUV patients revolves around the ultimate goal of preserving as much renal function as possible. The most important factor in determining eventual outcomes appears to be the degree of renal dysplasia [54]. It not only affects renal function early in life, but also limits the potential for the kidneys to meet the metabolic demands for future growth. Unfortunately, renal dysplasia and hyperfiltration are not presently correctable. Therefore, ongoing management of PUVs focuses on evaluating the baseline function of the urinary system and then addressing reversible causes of persistent or newly evolving damage.

Following valve ablation, a VCUG should be obtained to confirm complete valve ablation. For patients with a history of PUVs, presentation with new onset UTIs or incontinence should prompt a repeat VCUG to evaluate for residual valves or persistent vesicoureteral reflux. It is common for patients with PUVs to have persistent hydroureteronephrosis following valve ablation. Chronic dilation of the ureter and renal pelvis will not resolve immediately and does not likely represent continued obstruction from the ureterovesical junction [54]. A Tc-99m dimercaptosuccinic acid (DMSA) or MAG-3 renal scan should be obtained after 4–8 weeks of age to determine baseline differential renal function and identify nonfunctioning units. Also, because acidosis and salt-wasting nephropathy are commonly observed in patients with PUVs, frequent electrolyte evaluation should be performed to help tailor medical management. This is most often done in consultation with a pediatric nephrologist. For the urologist ongoing management addresses the causes of reversible renal damage: residual obstruction, bladder dysfunction and recurrent infections, including those associated with VUR [55, 56].

In patients with PUVs, it is important to optimize bladder function. In addition to the initial insult caused by the valves, over time chronic bladder distention at high pressures may lead to changes in bladder compliance and contractility. It is suggested that the progressive bladder failure is partly caused by polyuria resulting from the urine concentrating defect observed in patients with PUVs [19]. Urine production in these patients can range from 3 to 6 L per day. In addition, many of these patients lack normal bladder sensation, allowing them to retain large volumes of residual urine at high intra-vesical pressures without experiencing any pain. The combination of a noncompliant, thick-walled bladder, incontinence, and nephrogenic diabetes insipidus is a constellation of symptoms documented in patients with PUVs and termed "valve bladder syndrome" [57]. Long-term follow-up of patients with PUVs demonstrates discrete patterns of abnormal bladder function [58]. In infants and young children, urodynamic evaluation often demonstrates poor compliance; in older children, overactivity with uninhibited detrusor contractions predominates. In contrast, postpubertal patients with PUVs develop myogenic failure with large bladder volumes and weak, unsustained, and ineffective voiding contractions [59–61]. Many of these patients require clean intermittent catheterization.

Urodynamic studies of infant bladders are unlikely to provide information to guide management. Normal infant bladders are typically high pressure, low capacity systems. Urodynamic studies of infants with PUVs before and after valve ablation did not show an appreciable change

in bladder function or pressure. Furthermore, the elevated bladder pressures of infants do not portend poor future renal function [62]. Urodynamic studies of children with a history of PUVs, after infancy, can determine the degree of bladder dysfunction and guide treatment. Repeat urodynamic bladder evaluation should be conducted if previously identified vesicoureteral reflux persists, there is a breakthrough UTI, or new urinary incontinence develops. To alter the natural history of the valve bladder, early identification of bladder dysfunction allows conservative management such as anticholinergic therapy, double voiding, intermittent catheterization, or nighttime bladder drainage, depending on urodynamic findings, to protect the upper tracts and kidneys.

Vesicoureteral reflux occurs in 50–75 % of patients diagnosed with PUVs [63–65]. Most studies indicate that, in the majority of patients, the vesicoureteral reflux will ultimately resolve following valve ablation, but this resolution may take up to 3 years [54]. VUR into nonfunctioning renal units is not likely to resolve [42]. However, in the absence of recurrent urinary infections a nonfunctional refluxing kidney should be retained. This dilated ureter can be used for bladder augmentation in the future if bladder capacity/compliance is inadequate [66].

Bilateral vesicoureteral reflux is an independent risk factor for the development of chronic kidney disease in patients with PUVs [67, 68]. It is important to address the high-pressure, low-compliance bladder in PUV patients prior to attempting surgical intervention. Ureteral reimplantation performed in PUV patients who have not had these issues properly managed has a high complication rate [69]. Surgery should be reserved for those who fail conservative management or have significant VUR that interferes with normal voiding or is associated with persistent UTIs.

Despite appropriate medical and surgical management, some patients with PUVs will progress to renal insufficiency or chronic kidney disease [68, 70]. Kidney failure presents unique problems in the pediatric population. Adequate renal function is necessary for acid–base, electrolyte, and fluid homeostasis. These functions are not only necessary for life but for adequate growth and development. Renal function must also continue to increase as the child grows to meet the increased metabolic demands.

ESRD occurs in 25–50 % of patients with PUVs [71, 72]. One-third of these patients progress to ESRD within the first few months of life, and the remaining two-thirds progress during adolescence [71]. In one study in which patients with PUVs were followed for at least 10 years, 32 % had poor renal function, 6 % had chronic renal insufficiency, 15 % had ESRD, and 10 % died of renal failure [73].

Patients with PUVs who do progress to renal failure are candidates for renal transplantation. Several studies have found that the rates of transplant failure in children with and without a history of PUVs are comparable [74–76]. The bladder should continue to be managed as closely after transplantation as before transplantation.

Finally, patients with PUVs may develop problems with sexual function [77]. Erection and libido appear to be normal in patients without renal failure but impaired in patients with ESRD. Woodhouse et al. observed that 48 % of their adult patients with PUVs had slow or dry ejaculation. In the majority, this was because of failure of the posterior urethra to generate contractile forces; very few had retrograde ejaculation. Of the patients who underwent semen analysis, 40 % had poor motility or oligospermia, and 60 % had viscous semen with a pH above 8.0, suggestive of prostatic and seminal vesicle dysfunction. Very few patients actually fathered children.

Summary

PUVs are a common cause of congenital bladder outlet obstruction. In the past, children with PUVs were diagnosed after presenting with UTI, hematuria, urinary incontinence, or renal dysfunction. Today, the majority of male fetuses with PUVs are diagnosed in utero. Immediate postnatal stabilization requires the placement of a catheter for bladder drainage and adequate resuscitation. Appropriate radiological evaluation includes a renal/bladder ultrasound, a VCUG, and functional assessment of the kidneys such as nuclear renal

scan. Treatment includes endoscopic ablation of the valves, vesicostomy, and rarely, upper tract drainage. Close, long-term follow-up is necessary because the complications of PUVs are progressive and may not be evident for several years. Long-term complications include bladder dysfunction, incontinence, chronic kidney disease, and end-stage renal failure.

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Spina Bifida

25

Thomas S. Lendvay and Ruthie Su

Introduction

Neural tube defect is a general term for malformation of the central nervous system due to failure of neural tube closure during fetal development. The term spina bifida refers to the lack of closure of the neural tube below the head. The majority of cases (85 %) are in the caudal thoracolumbar spine or more distal. Spina bifida can be further categorized into: Meningocele, a sac-like protrusion of the meninges; myelomeningocele, protrusion of spinal cord elements along with the meninges; and lipomyelomeningocele, when fat tissue is present with the evaginating neural elements. Myelomeningocele is the most common form. Neurologic deficits occur due to a combination of failure of neural tube formation and exposure of neural elements in utero [1].

Pathogenesis

In normal development, the posterior neuropore closes and the neurocele (primitive central canal) becomes transiently occluded followed by rapid brain development. The most widely supported theory of spina bifida formation is that failure of the posterior neuropore and neurocele to completely close leads to cerebrospinal fluid flow out of the posterior neuropore, resulting in cerebellar herniation (Arnold Chiari II malformation) and hydrocephalus which is often present with myelomeningocele [1].

Epidemiological studies in the 1990s led to the discovery that maternal folate levels are critical for normal neural tube closure during pregnancy, although the exact biologic mechanism is unknown. In 1992, the US Public Health Service recommended that all women of childbearing age take 0.4 mg of folic acid daily [2]. Subsequently, the US FDA mandated folic acid fortification of grain products [3]. The incidence of spina bifida has subsequently decreased about 30 % to 3.4 per 10,000 live births in the United States from 1998 to 2006 [4, 5]. However, the etiology of spina bifida is multifactorial, as folate supplementation is not sufficient to completely abolish the occurrence of spina bifida. Maternal factors such as age younger than 19 years or older than 40 years, diabetes, and obesity have been shown to be risk factors for spina bifida. Caucasian and Hispanics are at higher risk for spina bifida than non-hispanic blacks [6].

Prenatal Intervention

It has been speculated that the spinal cord injury observed in myelomeningocele may be due to incomplete development of neural elements or prolonged exposure of neural elements to the

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intrauterine environment. In the case of the latter, it would seem that early closure would improve CSF flow, reverse cerebellar herniation, open cerebral spinal fluid drainage pathways and support more normal neurologic development. Fetal surgery of myelomeningocele has been performed since 1997 in a small number of institutions with variable success. To investigate the potential benefits of such surgery, the National Institute of Health sponsored a randomized controlled trial known as the Management of Myelomeningocele Trial (MOMS). Fetuses between 19 and 25 weeks gestation underwent repair of their myelomeningocele. Neurologic outcomes were compared to those who underwent standard postnatal closure. By 12 months of age, there was a 40 % rate of CSF shunt placement in the prenatal intervention group compared to 82 % in the postnatal intervention group ($P < 0.001$). The two groups were also evaluated at 30 months of age and the prenatal group was found to have better motor and cognitive function. These results so strongly indicated that fetal intervention permits more normal nervous system development that the trial was stopped early. The tradeoffs for these results, however, were more pregnancy complications (oligohydramnios, chorioamniotic separation, placental abruption, spontaneous membrane rupture), uterine scar defects, premature birth, and respiratory distress in the prenatal intervention group [7].

The effects of prenatal closure on bladder function unfortunately have been disappointing. The neurologic advantage afforded by fetal intervention has not been observed to extend to bladder outcomes [8, 9]. This was recently confirmed by a report of long-term urologic outcomes of fetal myelomeningocele closure [10]. Urodynamic data revealed no significant differences in bladder capacity, detrusor over activity, or detrusor pressures in the prenatal group and the majority still required clean intermittent catheterization and a bowel regimen. Thus, children who have undergone prenatal surgery for myelomeningocele will continue to require long-term urologic monitoring.

Urologic Treatment

Care for the patient with spina bifida requires a multidisciplinary approach. Immediately after birth, neurosurgical interventions take precedence to close the CNS defect and shunt the hydrocephalus. Once these neurologic issues have stabilized, the effects on bladder and bowel are addressed later in life. As children approach potty-training age and enroll in school, social continence takes the forefront in improving quality of life for children with spina bifida [11]. In addition, on-going follow-up is required to ensure that neuropathic bladder changes (high filling pressures, low compliance, small capacity, discoordinated bladder outlet function) do not impact renal health.

The goals of the urologist in taking care of the spina bifida patient are to preserve renal function and to help attain social continence. Many of the procedures performed throughout the life of a myelomeningocele patient are based on these aims. A bladder augmentation increases bladder capacity and decreases detrusor (bladder muscle) pressures to avoid upper tract damage. Use of the appendix or small bowel in the creation of an appendicovesicostomy or Mitrofanoff channel is often performed at the time of augmentation to increase compliance with intermittent catheterization in those who are obese, have decreased mobility or experience discomfort from urethral catheterization [12]. The appendix may also be used as an appendicocecostomy or antegrade continence enema (ACE) as a means to perform antegrade colonic enemas for fecal soiling or constipation [13].

Up to 20 % of Mitrofanoff channels will require correction of superficial skin stenosis, channel stricture, stomal prolapse, or channel incontinence, all of which usually occur within the first 2 years after surgery [12]. Similar complications may occur with the ACE stoma [13], but of highest morbidity is a bladder augmentation which confers lifelong risks of UTIs, bladder stones, bowel obstruction, metabolic disturbances, and bladder perforation [14].

Metabolic Disturbances

The ileum is most commonly used for bladder augmentation due to its availability, decreased mucous production, and abundant blood supply. Sometimes the colon may be preferable because of its proximity to the bladder and larger diameter thus needing a shorter segment [15]. The inclusion of bowel in the GU tract has several metabolic consequences because of the absorptive properties of the bowel mucosa. A hypokalemic, hyperchloremic metabolic acidosis can occur with the incorporation of either ileum or colon due to increased net absorption of ammonium chloride in the urine [16, 17]. In patients with normal renal function, the kidneys are able to accommodate the increased acid load, and the electrolyte disturbance is often not clinically significant [18]. In patients with preexisting renal insufficiency, however, a hyperchloremic metabolic acidosis can cause fatigue, anorexia, weight loss, polydipsia, or lethargy [19]. Additionally, profound hypokalemia due to intracellular potassium depletion occurring with a chronic metabolic acidosis can result in flaccid paralysis. A significant hypocalcemia can occur resulting in tetany, tremors, irritability, and death in severe cases as phosphates and sulfates from bone are used to buffer the excess acids [19, 20]. Treatment of the primary metabolic acidosis usually consists of alkalinization with sodium bicarbonate [21].

In patients with underlying renal insufficiency, gastrocystoplasty may be a more favorable choice of augment as the acid secretion and elimination from the stomach patch helps to counter the chronic acidosis from renal insufficiency. Without compensation, however, the electrolyte losses can result in a hypochloremic, hypokalemic metabolic alkalosis [22]. Under these circumstances, a GI disturbance causing dehydration can exacerbate the metabolic alkalosis and lead to symptoms of lethargy, mental status changes, or seizures. The treatment in these situations is fluid resuscitation with normal saline as well as potassium repletion. Patients should be instructed to maintain adequate hydration and salt intake [19]. The acidic environment provided by the gastric augment decreases the incidence of bacteriuria and does not secrete mucous, thus the incidence of bladder stones is decreased in gastric cystoplasty [23]. This acidity however can cause dysuria and hematuria from chronic irritation of the urothelium by gastric acid and can be a problem in patients with intact sensation [24].

The use of jejunum is without metabolic benefits and rarely ever considered except in patients with prior history of abdominopelvic radiation. The increased absorption of potassium and hydrogen with increased secretion of sodium and chloride leads to a hyponatremic, hypochloremic, hyperkalemic metabolic acidosis. These metabolic abnormalities can present with lethargy, nausea, vomiting, and muscle weakness. The loss of sodium chloride leads to a state of dehydration, stimulating the renin-angiotensin-aldosterone system. The increased potassium and decreased sodium in the urine perpetuates the electrolyte imbalances by setting up a concentration gradient that favors potassium reabsorption and sodium excretion by the jejunal segment [16, 19].

Bladder Stones

The risk of bladder stones is a well-known problem in bladder augmentation patients. The largest cystoplasty series to date describes a bladder stone incidence of 15 % [25]. The mean time from augmentation to first stone was 5.6 years and about 40 % of cases required 1.72 surgeries per patient. Chronic bacteruria, mucous production, and sutures or staples acting as foreign bodies are all possible factors that promote stone formation. The stones are usually struvite (magnesium ammonium phosphate) stones caused by chronic bacterial infection and can be removed either via open cystolithalopaxy or endoscopically. The efficacy between the two techniques is similar except that the percutaneous approach is associated with a faster recovery period [26]. Catheterization via an abdominal stoma is associated with a higher incidence of bladder stones compared to catheterization via the native urethra,

presumably because urethral catheterization more efficiently empties the bladder of accumulated mucous and debris [27]. Irrigation protocols with saline and gentamicin have been proposed to decrease the incidence of bladder stones [23]. Routine surveillance for bladder stones with plain abdominal radiograph or abdominal ultrasound is recommended.

Bladder Perforation

Bladder perforation after augmentation is potentially fatal and requires a high index of suspicion for prompt diagnosis and treatment. The bladder perforation rate reported in larger series ranges from 5 to 9 %, can occur as far out as 6 years from surgery, and its risk is unchanged for the life of the augmentation [28]. Chronic distention, noncompliance with intermittent catheterization, prior bladder outlet procedures which eliminate a "pop-off" mechanism, detrusor hyperreflexia, a non-tubularized bowel segment, or the configuration of a contracting bowel segment can increase bladder pressure and wall tension and theoretically lead to ischemia and perforation [29]. Diagnosis of bladder perforation is usually guided by clinical suspicion in the myelomeningocele patient, who may have altered sensation and therefore present in a delayed manner. A prior history of augmentation in a patient who presents with fever, abdominal pain, or sepsis should alert the emergency physician of possible spontaneous perforation. Confirmation can be made with radiographic imaging but false negatives may occur [30, 31].

There is controversy as to whether sigmoid colon used in cystoplasty confers a higher risk of perforation than ileum. Rupture of both types of augments has been reported although not directly compared [28, 29]. Perforation has least commonly been reported in gastric cystoplasties but this may be attributed to the infrequent use of that gastrointestinal substitute in present practice. The perforation is usually identified at laparotomy within the bowel segment or, if occurring early during the postoperative period, at the bladder–bowel anastomosis.

Distal ventriculoperitoneal shunt obstruction after bladder perforation has been described and usually presents with insidious onset of headache or fatigue within days of laparotomy. A head CT may show dilated ventricles. In a series of 27 patients with VP shunts who had undergone bladder augmentation, 4 patients experienced augment perforation and all developed a distal shunt dysfunction [32]. This led authors to suggest that at the time of bladder perforation repair, the shunt should empirically be externalized to avoid the risk of shunt dysfunction, which is not usually infectious but rather due to a resorptive problem with the peritoneum as a result of inflammation [33].

Radiologic Diagnosis of Bladder Perforation

Retrograde cystography is the standard imaging modality to diagnose bladder perforation. This is performed by placement of a urethral catheter followed by an abdomen X-ray as a scout film, followed by retrograde contrast administration to adequate distention with 350–400 cc (in patients age 2–11 the formula for bladder capacity may be used: (age +2 years) × 30 cc) [30]. A post-drainage film is essential because the contrast-filled bladder may obscure a small amount of extravasation on the 2D X-ray. Disadvantages include the requirement of a physician at bedside, time, and the need for multiple films [34].

CT cystography has been utilized and evaluated to be of similar accuracy as conventional cystography. This method entails retrograde administration of 350–400 cc of diluted contrast (16–29 mg of iodine/mL, compared to 150 mg L/mL used in conventional cystography) via a urethral catheter followed by CT scanning of the abdomen and pelvis, including the contrast-filled bladder. Extravasation of contrast into the peritoneal cavity can be seen with the bladder distended (Fig. 25.1). When the bladder is distended with contrast on CT, no post-drainage films are necessary since CT allows for 2D, cross-sectional images. Bone window settings may help to

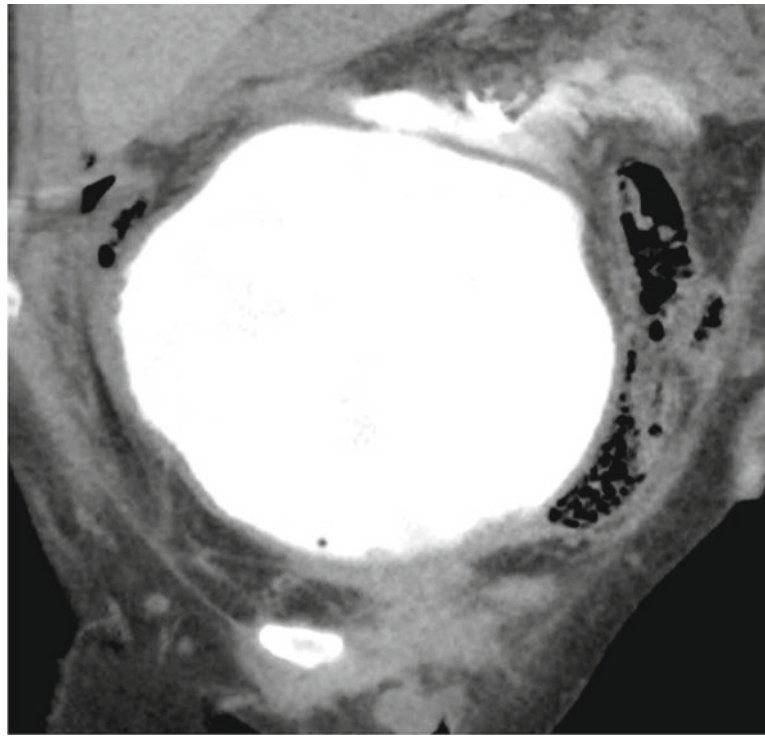

Fig. 25.1 Contrast extravasation on CT cystogram indicating bladder rupture in a patient with spina bifida and history of colocystoplasty

facilitate an evaluation of CT images. In the patient with contrast allergy, gadolinium has been described as a feasible non-iodinated substitute in CT cystogram [35].

Management

Perforation of the augmented bladder is by default an intraperitoneal bladder injury and can cause a potentially fatal peritonitis. Thus, the management is open surgical repair; intraperitoneal bladder injuries are less likely to spontaneously heal. Case reports have demonstrated the feasibility of conservative management with adequate bladder drainage using a large bore suprapubic cystostomy or urethral catheter, percutaneous drainage of the peritoneal urinoma, broad-spectrum IV antibiotics, and close observation. However, clinical deterioration in the first few hours of observation is an indication for emergent surgical intervention [36, 37]. If conservative management is successful, a retrograde cystogram is done prior to bladder catheter removal.

Conclusion

Recent identification of some of the risk factors for developing spina bifida as well as recent prenatal surgical interventions have helped reduce the incidence and sequelae of spina bifida. Yet, newborns with spina bifida require urgent urological evaluation, and eventually require major reconstructive surgery, which can lead to complications that emergency providers will see in their institutions. History and physical exam may not be straightforward due to altered mentation and altered genitourinary anatomy. Symptomatology is frequently atypical, and unrecognized complications from reconstructive procedures done through childhood can lead to rapid decompensation due to potentially limited metabolic reserve in these patients. Thus, we recommend that

diagnostics and treatment be led by a multidisciplinary team including the emergency providers, urologist, neurosurgeon, medical team, radiologist, and nephrologist to optimize patient care.

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