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REVIEW ARTICLE

Imaging of urinary bladder injury: the role of CT cystography

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Abstract

Although conventional radiographic cystography has been traditionally considered the reference standard in detecting bladder injuries, computed tomography (CT) cystography has become the initial imaging method of choice in the acute setting. CT cystography has been shown to provide comparable accuracy as conventional cystography, and can be easily performed in conjunction with trauma CT surveys in patients with suspected bladder injuries. Despite increasing enthusiasm toward CT cystography in dealing with patients with suspected bladder injuries, there is little information in this regard in the literature. This article aims to discuss the role of CT cystography in the evaluation of bladder injuries.

Keywords Urinary bladder · Trauma · CT cystography

Introduction

Abdominal trauma is a common reason for hospital admission in the USA. Up to 10% of patients sustain injuries to the genitourinary system [1]. Urinary bladder injury has been reported in 60–85% of cases with blunt trauma and in 15–51% of patients with penetrating injury [1, 2]. Iatrogenic etiologies are less common [3].

Urinary bladder injuries constitute 2–4% of abdominal surgical cases. They are often missed early on in multi-trauma patients, because life-threatening injuries are usually prioritized [4]. Misdiagnosis or delay in initiating appropriate management, however, can increase morbidity and mortality by 10–22% [5, 6]. Urinary tract infection, pelvic abscesses, urinary incontinence, and fistula have been reported as common complications of missed bladder trauma [7]. In this regard, proper imaging is of paramount importance in the triage of patients suspected of such injuries [8, 9]. Both conventional and computed tomographic (CT) cystography have been found highly accurate in detecting and grading bladder injuries [2].

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Anatomy

Anatomically, the bladder is a retroperitoneal organ firmly attached to the symphysis pubis at its neck. The remaining parts are unattached, allowing the bladder to distend and move freely upward during filling. The upper portion, or the "dome," of the bladder is an exception because it is lined by the visceral peritoneum and, unlike other parts, is therefore considered intraperitoneal. The dome is the weakest part of the bladder against trauma [10].

Mechanisms of injury

Because of its location deep within the bony pelvic structures in adults, an empty bladder is usually well protected against traumatic insults. When the bladder is distended and/or its bony shelter is fractured, however, it becomes susceptible to injury [11].

Overall, bladder injuries are categorized as traumatic (majority) or spontaneous. Instigating traumatic insults could be blunt, penetrating, or iatrogenic. Blunt and penetrating traumas to the bladder are frequently associated with pelvic fractures. While only 10–25% of patients with pelvic fracture sustain a simultaneous bladder rupture, over 75% of bladder injuries are complicated with pelvic fractures [12]. Combined bladder and urethral injuries are seen in 10–15% of patients [13, 14].

A full and elevated bladder is vulnerable to rupture at the dome by a direct blow to the lower abdomen, usually secondary to motor vehicle accidents (90% of cases) including ejection and compression of a seat belt on a full bladder. Other less frequent causes are falls, pelvic crush injuries/industrial trauma, and direct blows on the lower abdomen [13, 15, 16]. Bladder injuries after pelvic fractures are more likely due to a shearing force of vesical attachments to the bone and sometimes a result of bladder laceration by a fractured bone [11, 17]. Penetrating injuries may occur by gunshot or stab wounds [15].

Among the urologic organs, the bladder is the one that most often is subject to iatrogenic insult during surgery or instrumentation [18]. This type of injury is a full-thickness laceration, caused by external and internal procedures. Again, the common site is the dome, and in over half of the cases, the rupture is detected and corrected intraoperatively [19, 20]. In subtle or problematic cases, imaging plays a pivotal role in both detecting injuries and providing invaluable information to surgeons in deciding on an optimal therapeutic approach [21].

The most common causes of iatrogenic bladder injuries in the external category include urologic procedures, particularly retropubic male slings, as well as synthetic midurethral and pubovaginal slings, laparoscopic sacrocolpopexy, and transvaginal mesh surgery; obstetrics and gynecologic operations; and general surgery [18, 20–22]. In the internal category, transurethral resection of the bladder (TURB) and prostate (TURP) are more common [22, 23].

The chance of iatrogenic bladder injury increases when some risk factors such as anatomical abnormalities/manipulations, previous irradiation, obesity, infection, diabetes, and advanced malignancy preexist [18, 24].

Bladder ruptures occur spontaneously in rare cases, particularly in patients with urinary tract infection, bladder stones, urinary retention; in females with previous history of vaginal delivery; and in alcoholics and those who received radiotherapy [25].

Symptoms/clinical presentation

Gross hematuria is present in over 95% of patients with a bladder injury. Other indicators are microscopic hematuria, local pain and tenderness, ileus and abdominal distention, sepsis, elevated serum creatinine level, and voiding problems such as urinary leakage and diminished urinary output [13, 26, 27].

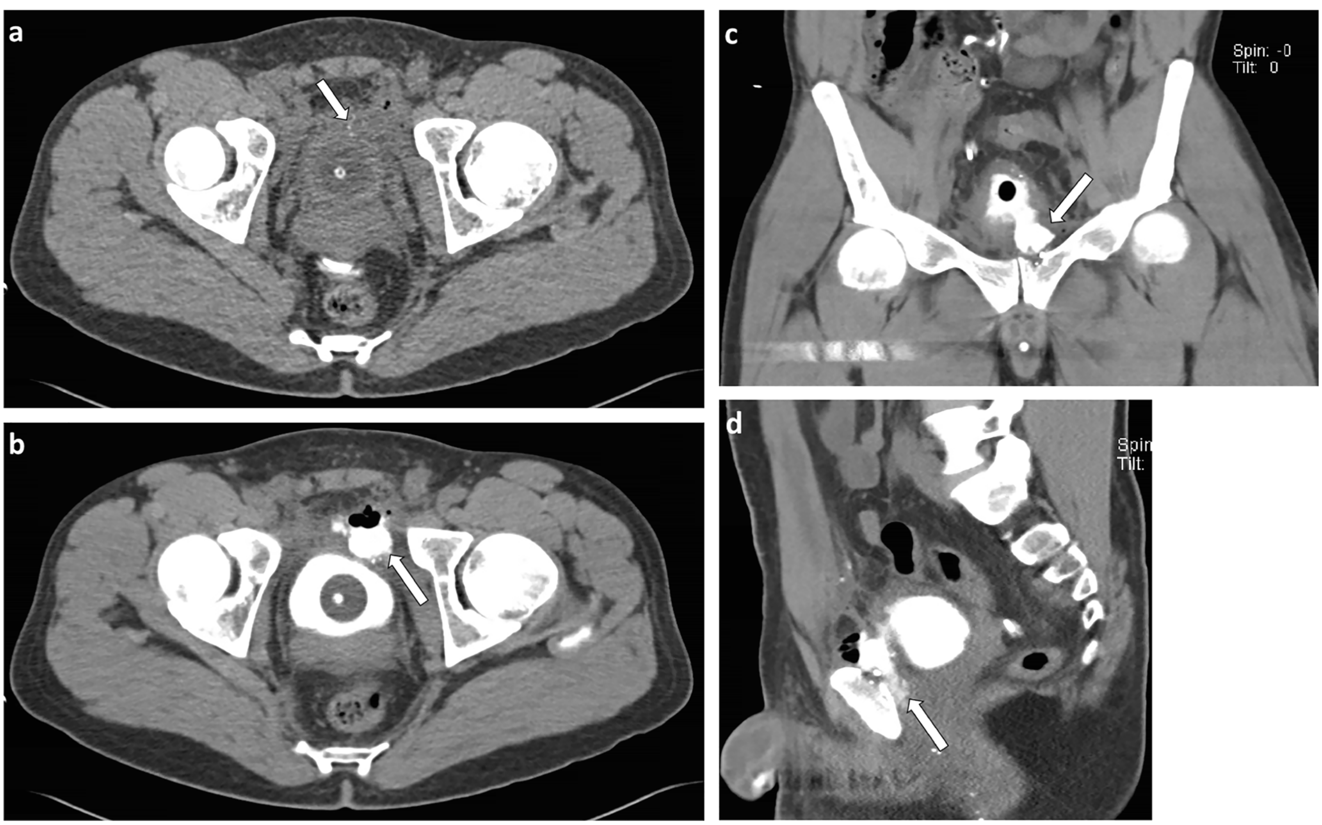

Fig. 1 A 27-year-old male with a bladder injury post-gunshot wound. Non-contrast CT scan did not show any significant bladder abnormality. A few hyperdense foci adjacent to the bladder represented bullet fragments (arrow) (**a**). CT cystography in axial (**b**), coronal (**c**), and sagittal (**d**) planes demonstrated extraperitoneal extravasation of the contrast material (arrows). The non-contrast image helped to differentiate bullet fragments from extravasated contrast

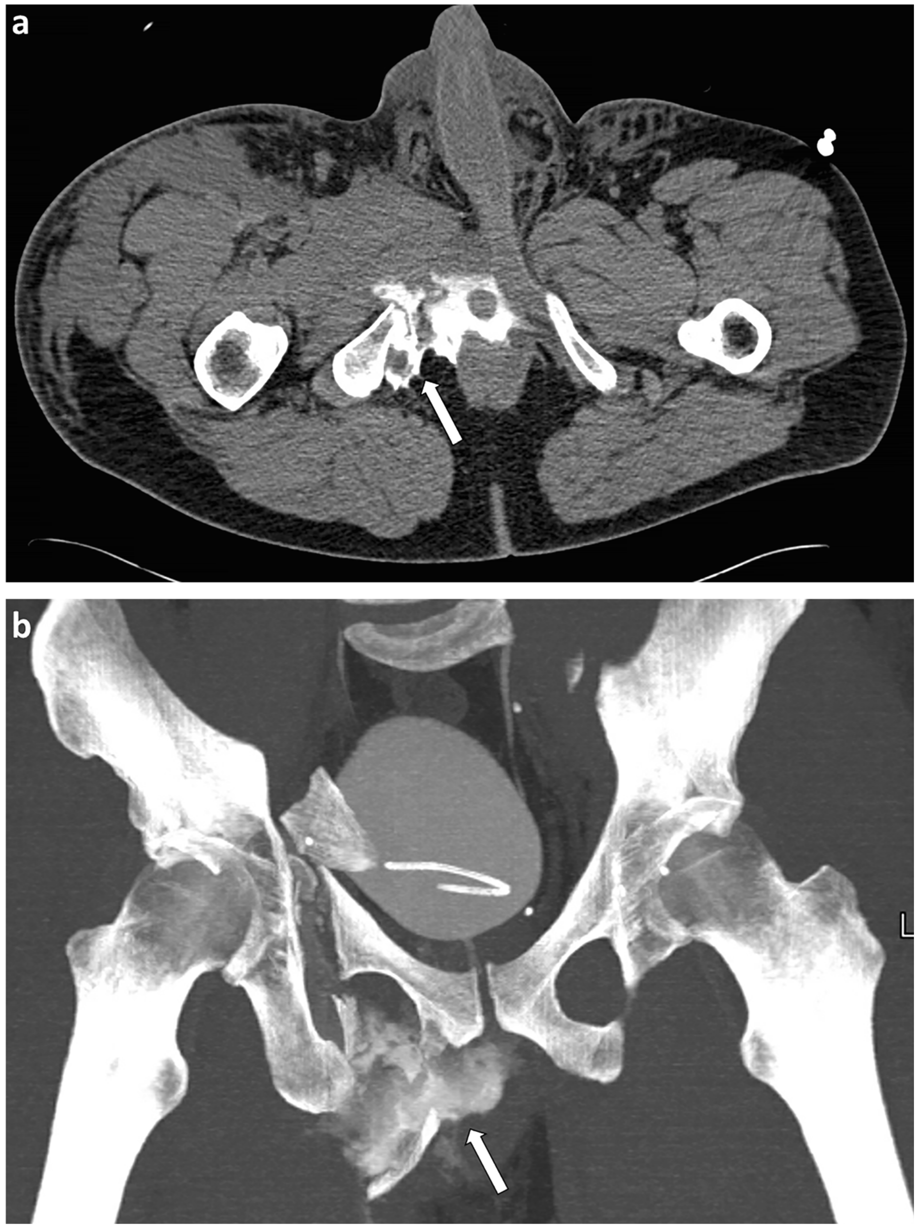

Fig. 2 A 40-year-old male with multiple pelvic fractures after being pinned at the pelvis by a truck against a loading dock. The patient presented with blood at the urethral meatus. Axial CT cystogram (**a**) showed extravasated contrast material in the base of the prostate (arrow) due to comminuted right pelvic fractures. CT cystogram in coronal maximum intensity projection (MIP) improved visualization of full extent of injury with contrast extravasation along the right of the urethra toward the right groin (arrow) (**b**). The smooth contour of the bladder dome confirmed the absence of concomitant intraperitoneal rupture of the bladder

Imaging techniques

In the past, conventional radiographic (retrograde) cystography was the mainstay imaging technique in examining patients with suspected bladder tears [28]. With the advent of CT, however, conventional cystography was increasingly replaced by the new technique. The initial CT examinations of the bladder were performed after intravenous administration of contrast material (i.e., anterograde opacification), but this technique was found considerably less sensitive than conventional cystography [28–33], primarily because the bladder must be distended and under pressure to reveal an injury [34]. Kane et al. [35] proposed delayed imaging to give the bladder sufficient time to distend adequately. Despite some improvements in image quality, this method increased scan duration, which would delay turnaround times in busy emergency departments and could delay addressing critical injuries. According to the American Association for the Surgery of Trauma (AAST; accessible from: www.aast.org), CT cystography is performed with retrograde filling of the bladder with 250–300 mL of iodinated contrast (50 mL diluted in 500 mL of sterile saline) after completion of routine (general) abdominopelvic CT in stable patients. Patients with potential bladder injuries most often suffer from a multisystem trauma that requires a routine CT examination [10, 36], so that both bladder injury and additional multisystem trauma can be assessed during the same exam. In our hospital, retrograde filling of the bladder with dilute contrast material is performed

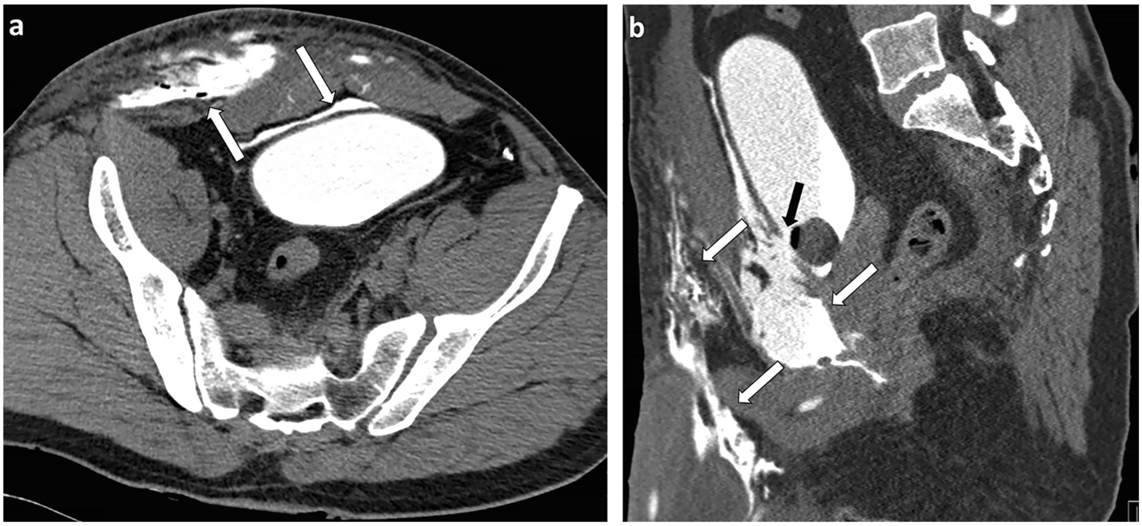

Fig. 4 A 43-year-old male involved in a motorcycle accident. CT cystogram in axial (**a**) and sagittal (**b**) views showed extraperitoneal contrast extravasation into the right abdominal wall and subcutaneous tissues (white arrows). The sagittal plane (**b**) more clearly depicted the location and extent of the bladder defect (black arrow) compared with axial plane (**a**)

prior to routine CT examination in the initial work-up of patients with suspected bladder injury.

CT cystography protocol

At our institution, bladder catheterization is performed by the trauma surgery team after urethral injury has been excluded based on clinical exam or retrograde urethrogram. This is especially important in the presence of concomitant pelvic fractures, bleeding in the meatus, voiding problems, high-riding prostate, and swelling in the scrotum [10]. CT cystography is performed on a dual-source multidetector CT (SOMATOM Definition FLASH or SOMATOM Definition DRIVE, Siemens Healthineers, Erlangen, Germany). Acquisition parameters are optimized for each individual patient to minimize radiation dose, but are on the order of 100–120 kVp, 290 reference mAs, pitch 0.6, tube rotation time, and 128 × 0.6 mm collimation. Images are reconstructed into 0.75 mm and 3 mm slice thickness with coronal and sagittal reconstructions. Maximum intensity projection (MIP) and volume-rendered (VR) images are generated from a volumetric view of the block.

The imaging protocol includes a non-contrast phase limited to the bladder, followed by full bladder and post-void images. The non-contrast phase is essential for identifying intrinsically hyperdense material (e.g., surgical material, bullet fragments, and calcifications) that can be mistaken for extravasated contrast material. Then, the urine is drained via a Foley/suprapubic catheter, and a water-soluble contrast material (30 mL nonionic contrast/500 mL saline solution) is instilled into the bladder under the pressure of gravity until either a feeling of urgency (or discomfort) by the patient or more than 300 mL of diluted contrast solution is administered. The final step is post-void; during which, the bladder is drained after imaging is accomplished. In the case of persistent enhancement, a bladder wall injury may exist [37–39] (Fig. 1).

Advantages

In an optimal setting, i.e., obtaining images after having the bladder adequately distended and post-voiding, the sensitivity and specificity for both conventional and CT cystography can reach 95% and 100%, respectively, in detecting bladder ruptures [7, 33, 34, 40]. CT cystography, however, has several extra advantages compared with conventional cystography. First, CT cystography and conventional abdominopelvic CT can be performed simultaneously, without the need for transferring an acutely ill patient to the fluoroscopy suite [34]. This approach could prevent higher radiation exposure and additional cost associated with a separate study with conventional cystoscopy [39]. Further, during conventional cystography, the patient needs to be positioned in oblique planes to assess bladder integrity, which can be technically challenging in patients with pelvic fractures. With CT cystography, the patient can remain in the supine position for the duration of the exam, without the need for oblique views. Second, CT cystography can detect subtle leakages that can be obscured by the distended bladder, superimposed bowel, or bones with conventional cystography due to its ability to resolve overlapping structures [21, 33]. This substantially increases the sensitivity of CT cystography in detecting injury and classifying patterns of bladder injury [13, 22, 25, 31, 33, 40–45]. Multiplanar reconstructions and 3D reformations can illustrate the extent of injury [34] and may assist in management decisions (Figs. 2–4). Furthermore, unlike conventional cystography, which provides information confined to the bladder and close

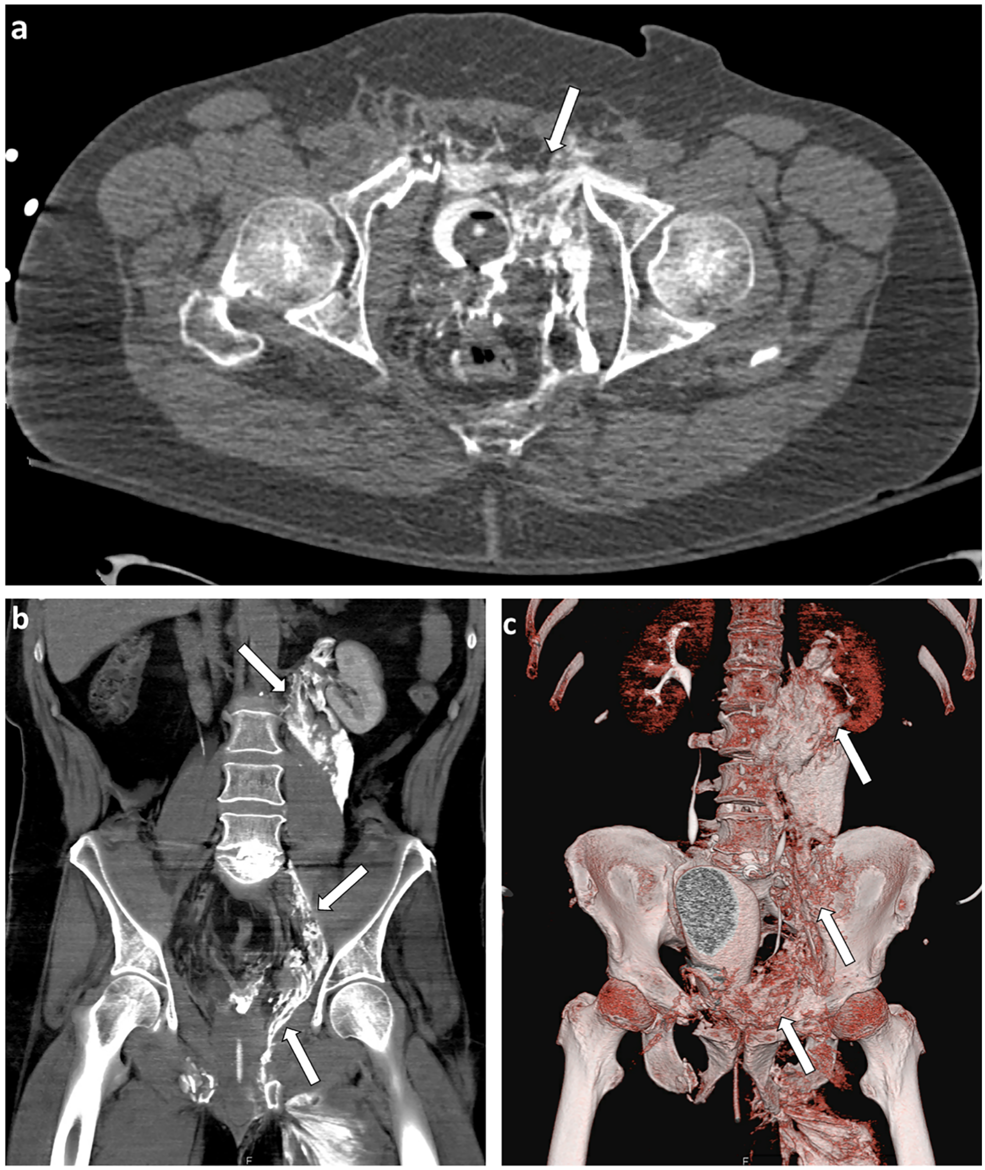

Fig. 3 A 57-year-old male after a motorcycle collision with extensive sacral and pelvic fractures. CT cystogram in axial (**a**) and coronal (**b**) planes showed extensive extraperitoneal contrast material extravasation. Note the contrast material seen in the retropubic space (arrow) (**a**). contrast material tracks along the left pelvic sidewall into the left perineum and into the left adductor muscles of the left thigh. Small amounts are seen in the right adductor muscles. Moderate amount of contrast noted to track along the left psoas muscle to the level of the left kidney (arrows) (**b**). The extensive contrast material extravasation is nicely defined on the volume-rendered 3D image (arrows) (**c**)

surroundings only, CT cystography extends the examination field beyond the bladder, especially when it complements a general abdominopelvic CT [34, 43]. This allows for efficient examination of not only the bladder configuration and its lumen, but also the genitalia, pelvic bones (Figs. 1–3), surrounding intraperitoneal and extraperitoneal areas, and local gastrointestinal tract [33, 39, 44, 46], as well as the ready detection, localization, and simultaneous classification of any abnormal fluid collection in the pelvis, such as hematoma, abscess, lymphocele, and urinoma [47].

Classification

A commonly used classification system of bladder injury consists of contusion, intraperitoneal rupture, extraperitoneal rupture, and combined intraperitoneal and extraperitoneal rupture [13, 34].

At imaging, a contusion can manifest as hematoma within the bladder wall with or without bladder outline distortion, representing a partial tear of the mucosa or muscularis layer with preservation of the full-thickness wall continuity. Since many contusions remain asymptomatic clinically and in imaging, the true incidence is hard to estimate. Intraperitoneal bladder ruptures are usually seen in less than 20% of patients following a sudden rise in intravesical pressure in an already distended bladder. Because of its high mobility and weak protection, the dome is the most commonly involved part of the bladder, leading to intraperitoneal leakage of the contrast material. The extravasated material may fill the cul-de-sac, rectovesical pouch, or paracolic gutter, and/or outline the intra-abdominal viscera, the bowel loops in particular (Figs. 5 and 6). Extraperitoneal ruptures

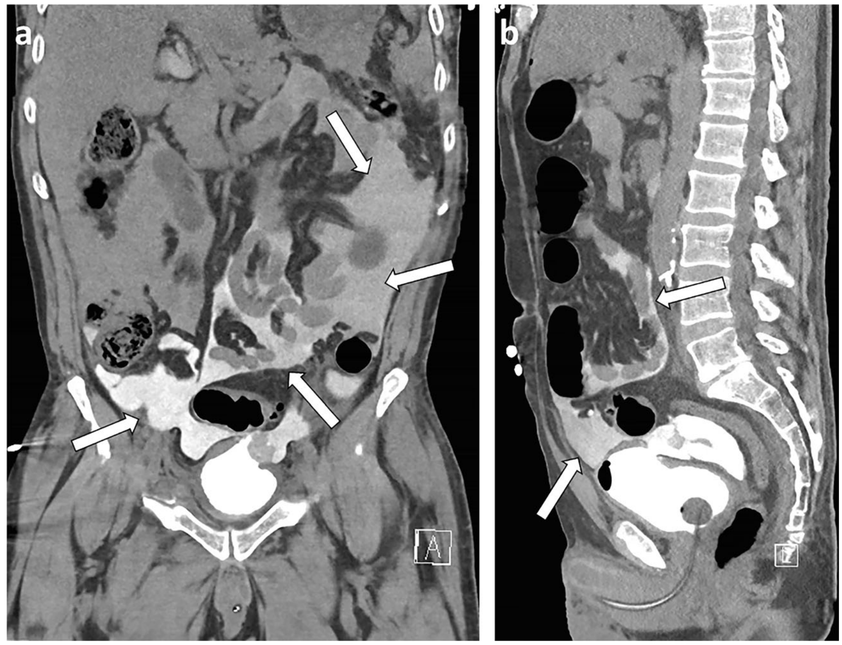

Fig. 5 A 52-year-old male with pelvic fracture after a car accident. CT cystography reveals extensive intraperitoneal contrast material extravasation, wrapping around the small intestine loops on coronal (**a**) and sagittal (**b**) images (arrows), a feature typical of intraperitoneal bladder rupture

constitute the most frequent type of bladder injury (> 80%) (Figs. 1–4). This type of injury is often associated with pelvic fractures. Lacerations are usually spotted on the anterolateral wall in proximity to the bladder base (Fig. 2), unless a bony spicule penetrates the wall directly. Extravasation may accumulate in the perivesical (Retzius) space, producing “flame-shaped” areas

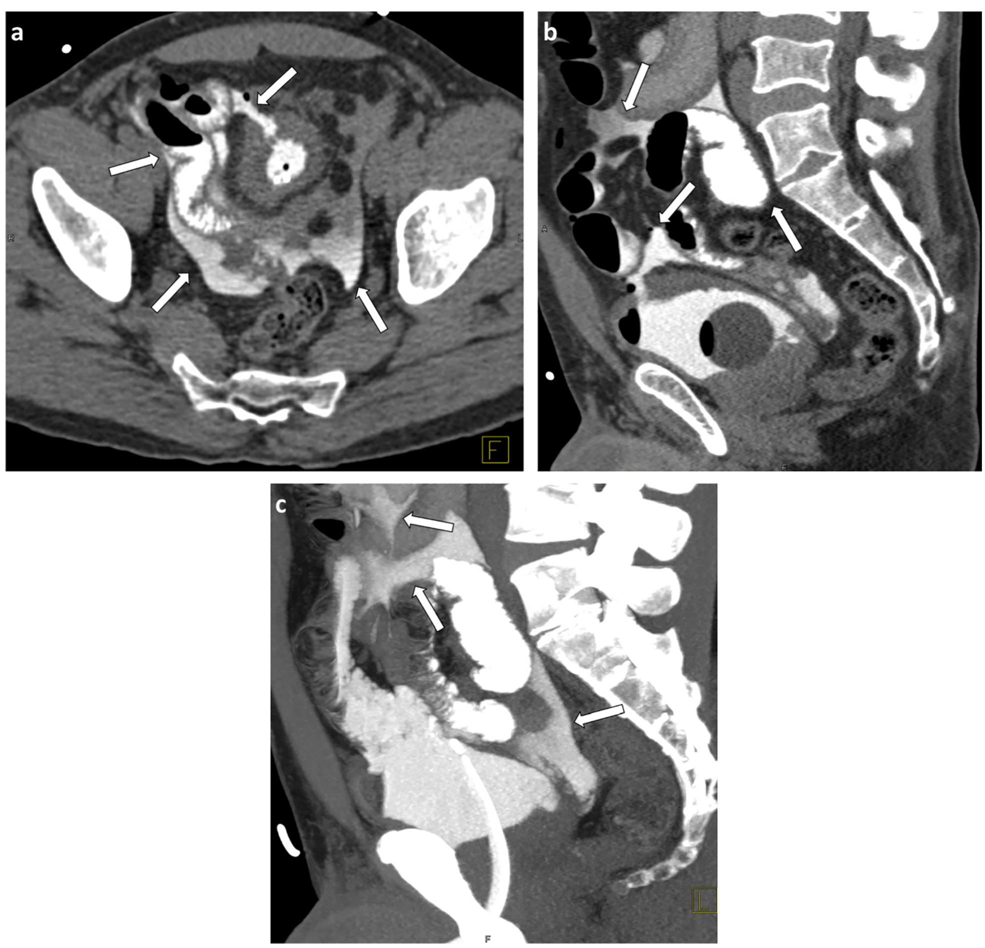

Fig. 6 A 34-year-old male presenting with increasing abdominal pain and history of prior bladder rupture. CT cystography in axial (**a**) and sagittal (**b**) planes show intraperitoneal contrast material extravasation, which extends between bowel loops as well as into the mesentery and subhepatic space throughout the peritoneal cavity (arrows). CT cystogram in sagittal maximum intensity projection (MIP) (**c**) may be helpful in demonstrating the full extent of the injury

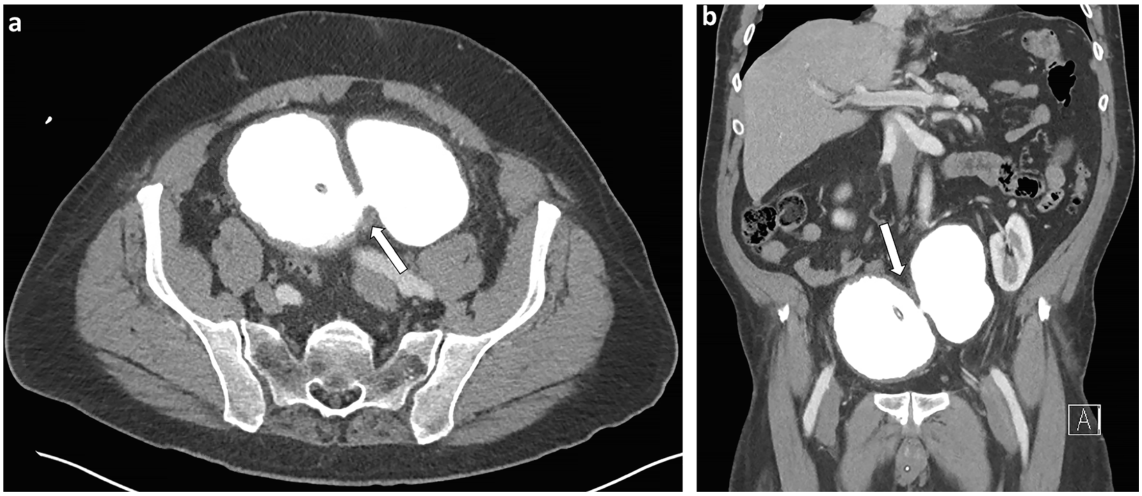

Fig. 7 A 74-year-old male with a bladder diverticulum (arrows). CT cystogram in axial (**a**) and coronal (**b**) planes showed a well-circumscribed collection of contrast along the left lateral bladder wall connected via a thin neck (arrow). The well-circumscribed nature of this contrast collection differs from the ill-defined contrast collections in intraperitoneal and extraperitoneal bladder rupture

or a so-called molar tooth appearance on axial images (simple extraperitoneal bladder tear), or may extend beyond the perivesical space to the thigh (via the obturator foramen), scrotum (via the inguinal canal), anterior abdominal wall, or the retroperitoneal compartment (complex extraperitoneal bladder tear) (Figs. 3 and 4) [13, 48]. A combined intraperitoneal and extraperitoneal condition may be seen in 12% of patients. Patterns of extravasation in the combined category are typical for both intraperitoneal and extraperitoneal injuries [25, 39].

Management

Patients with an intraperitoneal component (alone or in combination) require surgical intervention. Urethral catheter drainage and observation, however, are adequate in cases with isolated extraperitoneal injuries, and a conservative approach has been proved ideal for managing contusions [28]. This is why an accurate identification and classification of a suspected bladder injury is of great clinical importance, as imaging clearly plays a critical role in this regard [39].

Pitfalls

Like with conventional cystography, bladder under distention can dramatically decrease the accuracy of CT cystography in detecting lesions [7]. Although rare, interstitial bladder injury, which is defined as partial-thickness or intramural lacerations with intact overlying serosa, may pose a diagnostic challenge using CT cystography [39]. Bladder diverticulum, which appears as a well-circumscribed collection of contrast beyond the expected confines of the bladder, can be a potential mimicker of acute bladder injury. The borders of the bladder diverticulum should be smooth, as opposed to the ill-defined contrast collection as seen with intraperitoneal or extraperitoneal bladder injury (Fig. 7). Although with low probability, the tip of an inserted Foley catheter may cover a rift in the bladder wall, preventing sufficient contrast extravasation required for revealing an injury. Conversely, when the site of a rupture in a case with combined intraperitoneal and extraperitoneal injury is large, most of the contrast material extravasates into the extraperitoneal compartment owing to insufficient bladder distention, leading to a false clinical interpretation. sufficient bladder distention may be precluded by the presence of a large intrapelvic hematoma/fluid collection [49]. The presence of an intravesical clot may also prevent CT cystoscopy from revealing a bladder rupture [7]. Finally, another important caveat is a false negative finding at CT cystography, possibly due to the spasm of the detrusor muscle in reaction to the irritating effect of the contrast material, which may cause a leak to become temporarily sealed [50].

Conclusion

Compared with conventional cystography, CT cystography can expedite triage of patients with suspected urinary bladder trauma and as an adjunct to routine abdominopelvic CT in multi-trauma patients, and is more accurate in detecting as well as classifying patterns of bladder injury. Although these advantages can potentially decrease radiation exposure and cost, future studies are required to further substantiate existing evidence.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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