

The background of the cover is a vibrant red color. At the top and bottom, there are microscopic images showing cells and bacteria. The bacteria have long, thin, wavy flagella. The cells are spherical and some have internal structures visible. The overall theme is medical and scientific.

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Urinary Tract Dysfunctions - Underestimated Health Issue

New Insight in Diagnosis, Treatment
and Management

Edited by Giovanni Palleschi



Urinary Tract Dysfunctions
- Underestimated Health
Issue - New Insight in
Diagnosis, Treatment and
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Meet the editor



Giovanni Palleschi (MD, Ph.D.) graduated in Medicine in 1997 and specialized in Urology in 2002, both at Sapienza University of Rome, where he gained a grant for research on voiding disorders in patients with Multiple Sclerosis (2002) and completed a physician doctorate in human anatomy, plastic surgery, and dermatology in 2011. In his career, he attended a Master's in Laparoscopic Surgery in Strasbourg (IRCAD), an International Master's in Laparoscopy (Sapienza University of Rome and Carol Davila University of Bucharest), and a Master's in Kidney Transplant at Tor Vergata University of Rome. He has been a member of Scientific Committees for the Italian Society of Urodynamics, the European Association of Urology, and the Italian Society of Urology; a Co-Investigator in many Clinical Trials; and a Scientific Consultant for various pharmaceutical companies. He has published many articles indexed in PubMed, and he is an author and co-author of various scientific books. He won 6 scientific awards and participated in Academic Activities (teaching) at Sapienza University of Rome. At present, he works for the Nefrocenter Group in Italy.

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Preface

Urinary tract dysfunction includes various disorders of the upper and lower urinary tract that are prevalent in the general population. Among the most important conditions are congenital abnormalities, urinary incontinence, neurogenic bladder, and bladder outlet obstruction problems that are primarily the consequence of prostatic hyperplasia, urethral strictures, or, in women, genital prolapse. Due to its benign characteristics, urinary tract dysfunction is still an underestimated health issue. However, untreated urologic dysfunctions may lead to severe complications that can become a risk to life. In fact, when symptoms are mild, a therapeutic approach may be conservative, allowing for the achievement of objective and subjective favourable outcomes without invasive strategies. One of the most important aspects of urinary tract dysfunction is that some conditions have a severe negative impact on quality of life. Urinary incontinence, as an example, reduces work activity, social interaction, sport practising, and sexual activity. These aspects should lead to not underestimating urinary tract dysfunction, especially considering that these disorders contribute to a significant economic burden on sanitary systems. Some topics in urinary tract dysfunction are poorly discussed in the general literature, which tends to focus on main arguments. Pediatric urologic disorders are scarcely known because they are usually managed only by specialists. However, these pathologic conditions that are often the consequence of congenital abnormalities deserve great attention because they can be misdiagnosed and can become responsible for complications capable of causing renal failure, reducing life expectancy. All these topics are well discussed in the book's chapter. In Section 1, diagnostic assessment, clinical aspects, and strategies to manage complications of urological dysfunction, either in pediatrics (Chapter 1) and in adults, are reported, with special attention to urogenital fistulas (Chapter 2). Urologic dysfunction diagnosis often represents a challenge; diagnostic tools play a crucial role in defining the disorder's pathophysiology. That is the reason why Section 2 of the book is dedicated to radiologic assessment. First, videourodynamics and its application in various functional disorders are reported (Chapter 3); this section is enriched with radiologic images illustrating specific cases. Secondly, a general overview of radiology's role in the assessment of urinary incontinence is provided (Chapter 4). Finally, Section 3 is dedicated to therapeutic approaches to benign prostatic hyperplasia, with a focus on laser surgery (Chapter 5). The authors who participated in this project are all experts in this important field of urology, and I want to thank all of them and their co-authors for their valuable contributions and efforts.

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Section 1

Urologic Complications
in Pediatric and Adult Ages

Chapter 1

Complicated Considerations in Pediatric Congenitalism

Marvin A. Simpkins, Aidan Weitzner and Chad Crigger

Abstract

Pediatric congenital anomalies of the genitourinary tract represent a heterogeneous group of disorders that may lead to significant morbidity, including renal scarring, hypertension, recurrent urinary tract infections, and bladder dysfunction. This chapter reviews the embryology, epidemiology, natural history, and clinical spectrum of key conditions – ureteropelvic junction obstruction, posterior urethral valves, vesicoureteral reflux, ureteroceles, duplex collecting systems with ectopic ureters, bladder exstrophy–epispadias complex, and neurogenic bladder – highlighting their pathophysiology and diagnostic nuances. We examine current imaging strategies (ultrasound, voiding cystourethrography, MR urography) and urodynamic techniques for functional assessment, emphasizing tailored approaches across disease types. Management principles are discussed with attention to timing and choice of intervention: from endoscopic incision for ureteroceles and valve ablation to open and minimally invasive reconstructive techniques in complex anomalies, alongside bladder rehabilitation and catheterization protocols in neurogenic cases. Long-term outcomes, including renal preservation and quality-of-life metrics, are considered, underscoring the importance of lifelong surveillance. Emerging technologies – robotic surgery, tissue engineering, and advanced biomarker research – offer promise for less invasive correction and personalized care. Finally, we advocate for multidisciplinary collaboration and standardized outcome registries to refine evidence-based guidelines and support future innovations in pediatric urology.

Keywords: posterior urethral valves (PUVs), bladder exstrophy, lower urinary tract obstruction, spina bifida, nephrology, urinary tract anomalies

1. Introduction

Congenital anomalies of the kidney and urinary tract (CAKUT) represent a leading cause of pediatric chronic kidney disease (CKD) and end-stage renal failure worldwide, accounting for up to 30–50% of cases in children requiring renal replacement therapy (RRT) [1, 2]. Beyond their long-term impact on glomerular filtration and growth, these anomalies predispose patients to recurrent urinary tract infections (UTIs), hypertension, and impaired quality of life well into adulthood [1].

Early recognition and management are, therefore, critical to preserving renal function and minimizing morbid sequelae.

Clinicians categorize CAKUT into broad mechanistic groups – obstructive lesions, refluxogenic anomalies, and bladder-dysfunctional conditions – to guide diagnostic evaluation and therapeutic planning [3]. This functional classification aligns with underlying embryologic disruptions: Aberrant ureteric bud branching and metanephric mesenchyme interactions give rise to obstruction and dysplastic change, whereas malpositioning of the ureteral orifice and urethral sphincter dysfunction underpin reflux and voiding disorders, respectively [4, 5]. Understanding these developmental pathways provides insight into variable phenotypes and informs the selection of interventions ranging from endoscopic correction to reconstructive surgery.

Epidemiologically, CAKUT affect approximately 3–6 per 1,000 live births, with a slight male predominance and a right-sided bias in unilateral presentations [6, 7]. The spectrum spans isolated duplex systems or ureterocele to complex syndromic forms such as prune-belly syndrome (PBS) and bladder exstrophy (BE). We will discuss the full array of pediatric urologic congenital anomalies in the later sections.

2. Roadmap and overview of pediatric urinary tract congenital anomalies

We will begin by systematically reviewing eight core congenital anomalies: ureteropelvic junction obstruction (UPJO), PBS, duplex collecting systems with ectopic ureters, ureterocele, vesicoureteral reflux (VUR), posterior urethral valves (PUVs), bladder exstrophy–epispadias complex, and neurogenic bladder (e.g., myelomeningocele, tethered cord). For each entity, we will summarize its epidemiology, underlying developmental pathophysiology, typical clinical presentation, and current management strategies, with a summary provided in **Table 1**. Thereafter, Section 4 will highlight cross-cutting diagnostic considerations (imaging modalities, urodynamic assessment, and genetic evaluation), followed by discussions of emerging techniques and long-term outcome expectations.

3. Anomaly-specific

3.1 Ureteropelvic junction obstruction

Ureteropelvic junction obstruction results from impaired drainage at the junction of the renal pelvis and proximal ureter, most commonly due to aperistaltic intrinsic muscular discontinuity or extrinsic vascular compression (**Figure 1**). Embryologically, UPJO is attributed to aberrant migration and remodeling of the ureteric bud and adjacent metanephric mesenchyme during 5–10 weeks of gestation, resulting in a noncontractile segment at the ureteropelvic junction [8, 9].

The incidence of prenatally detected hydronephrosis attributed to UPJO is about 1 in 1,500 live births, with male predominance (~2:1) and a 60% left-sided bias [8, 10]. Mild-to-moderate hydronephrosis (SFU Grades 1–2) spontaneously resolves in 70–80% of cases by 12–24 months of age [11], whereas high-grade dilatation (SFU Grades 3–4) is associated with increased ultrasound (US) scores predictive of the need for pyeloplasty, with Li et al. demonstrating that scores ≥ 7 conferred a 90%

Condition	Prevalence	Presenting symptoms	Diagnostic tests	Treatment
UPJO	1:1500	Prenatal hydronephrosis; postnatal flank mass, pain, or febrile UTI.	Renal/bladder US, diuretic renography (MAG3), and MR urography.	Observation if stable; pyeloplasty (open, laparoscopic, or robotic) for obstruction.
PBS	1:30000	Abdominal wall laxity, bilateral urinary tract dilation, cryptorchidism; recurrent UTIs.	Prenatal US, renal/bladder US, VCUG, and genetic testing if suspected.	Staged abdominal wall reconstruction, orchiopexy, bladder/ureteral reconstruction, and UTI prophylaxis.
Duplex collecting systems and ectopic ureters	1:125	Often asymptomatic; recurrent UTIs, urinary incontinence (in girls); hydronephrosis.	Renal/bladder US, VCUG, MR urography, or CT for anatomy.	Observation if stable; heminephrectomy, ureteroureterostomy, or reimplantation for obstruction or reflux.
Ureterocele	1:4000	Recurrent UTIs, incontinence, prenatal or incidental detection, and hydronephrosis.	Renal/bladder US, VCUG, and diuretic renography to assess moiety function.	Endoscopic puncture/incision; staged reconstruction or heminephrectomy for nonfunctioning segments.
VUR	1:100	UTI.	Renal and bladder US, VCUG, and DMSA.	CAP, deflux injection (low grade), ureteral reimplantation (persistent high grade).
PUV	1:10000	In utero: Presentation ranges from asymptomatic to massive bladder distention with renal aplasia, lung hypoplasia, and soft tissue deformities (Potter's syndrome). Postnatal: UTI, bladder distention, and hydronephrosis.	Renal and bladder US, cystoscopy, and VCUG.	Surgical management involves TURV or vesicostomy.
Bladder exstrophy-epispadias complex	1:50000	Externalized bladder, epispadias, iliac crest widening.	Prenatal US and physical examination at birth, followed by follow-up studies including VCUG and CMG.	Surgical management includes bladder closure and osteotomy, as well as bladder neck reconstruction versus bladder neck transection with bladder augmentation and the creation of a continence channel during adolescence.
Neurogenic bladder	1:3000	Presents with concurrent spina bifida and myelomeningocele. If untreated: bladder distention and UTI.	Renal and bladder US, urodynamic studies, and CMG.	CIC regimen, anticholinergics, Continuous Ambulatory Peritoneal (CAP, or vesicostomy (if symptoms are severe or CIC cannot be achieved).
Renal aplastic dysplasia	0.8–1:1000	UTI, pelvic pain in females, and pelvic pain/subfertility in males.	Prenatal US, follow-up VCUG for UTI. Consider genetic studies.	Observation with risk-tiered lifelong follow-up for kidney-protective counseling.

Table 1.
Summary of major congenital anomalies of the pediatric urinary tract: epidemiology, presentation, and management strategies.



Figure 1.

Right retrograde pyelogram showing an abrupt directional change at the ureteropelvic junction, which was determined to be caused by a major crossing vessel at the time of robotic-assisted laparoscopic pyeloplasty. From the personal library of Chad Crigger with patient permission.

likelihood of surgical intervention [12]. Long-term renal outcomes correlate with initial SFU grade and split renal function on diuretic renography; notably, Babu et al. showed that early pyeloplasty (performed within 6 months of diagnosis) leads to significantly greater improvement in differential renal function compared with delayed intervention [13].

Postnatal diagnostics begin with renal US to confirm hydronephrosis and assess cortical thickness. Diuretic renography using 99 mTc-MAG3 provides split renal function and drainage parameters; a $T_{1/2} > 20$ minutes and a $> 10\%$ decline in split function on serial scans indicate significant obstruction [8, 14]. MR urography offers three-dimensional anatomical detail and high-resolution functional curves without ionizing radiation, aiding surgical planning in complex or bilateral cases [15]. The use of urodynamic studies is reserved for patients with coexisting bladder dysfunction or a suspected neurogenic component.

Conservative management – serial US every 3–6 months and periodic renography – is appropriate for infants with preserved differential function ($> 40\%$), nonobstructive drainage curves, and absence of symptoms [11]. Surgical indications include symptomatic obstruction (pain, infection), progressive loss of function ($> 10\%$ decline), or worsening hydronephrosis (SFU grade increase) [8, 11]. Open

Anderson–Hynes dismembered pyeloplasty has long been considered the gold standard, with success rates >95% [16]; however, laparoscopic and robot-assisted approaches now demonstrate equivalent efficacy with reduced postoperative pain and shorter hospital stays, making them increasingly preferred in many centers [16, 17]. Recent evidence demonstrates that stent-less pyeloplasty is associated with reduced postoperative pain and lower UTI rates compared with stented approaches [17].

3.2 Prune-belly syndrome

Prune-belly syndrome, also known as Eagle–Barrett syndrome, is defined by the classic triad of abdominal wall musculature deficiency, bilateral urinary tract dilatation, and cryptorchidism in males [18, 19]. The underlying pathogenesis is multifactorial: Failure of mesodermal migration leads to hypoplastic abdominal musculature, while abnormal ureteric bud–metanephric interactions contribute to urinary tract dysplasia and obstruction [18]. Histologically, smooth muscle dysplasia and connective tissue proliferation are frequently observed in the ureter and bladder walls, resulting in functional obstruction and progressive renal parenchymal damage [20].

The reported incidence of PBS ranges from 1 in 30,000 to 1 in 40,000 live births, with a striking male predominance (>95%) [21]. A national review of the Kids' Inpatient Database from 1997 to 2009 found that the birth prevalence of PBS remained essentially stable – declining only from 4.8 to 3.3 cases per 100,000 uncomplicated births ($p = 0.44$) – while other complex genitourinary anomalies showed significant shifts in incidence [22]. Severity varies widely, prompting the development of phenotypic scoring systems that categorize patients based on abdominal wall defect, urinary tract dilatation, and renal function [23].

Although most PBS cases are sporadic, emerging genetic studies have identified causative variants in key developmental genes. Hemizygous missense mutations in the X-linked *FLNA* gene have been linked to a subset of familial PBS cases, implicating filamin A in the cytoskeletal integrity of developing smooth muscle [24]. More recently, compound heterozygous loss-of-function mutations in *PIEZO1* have been described, underscoring the role of mechanotransduction in abdominal wall and urinary tract morphogenesis [25]. These findings suggest genetic heterogeneity and provide targets for future molecular diagnostics.

Prenatal diagnosis of PBS is now achievable in the second trimester via detailed ultrasonography. Characteristic findings include a distended bladder with a “keyhole” sign, oligohydramnios, and markedly thin abdominal wall musculature [26]. Early detection allows for multidisciplinary counseling and, in selected cases, fetal interventions such as vesicoamniotic shunting to preserve renal function [21, 26].

Clinically, PBS manifests with recurrent UTIs, nephrolithiasis, and progressive renal insufficiency, alongside gastrointestinal issues arising from the lax abdominal wall [27]. Management is tailored to the severity of the phenotype and may include staged abdominal wall reconstruction, ureteral reimplantation, and bladder augmentation to optimize storage and emptying [18, 27]. Extra-genitourinary malformations – such as pulmonary hypoplasia, musculoskeletal anomalies, and cardiovascular defects – occur in up to 30% of cases and necessitate comprehensive evaluation [19] (**Figure 2**).

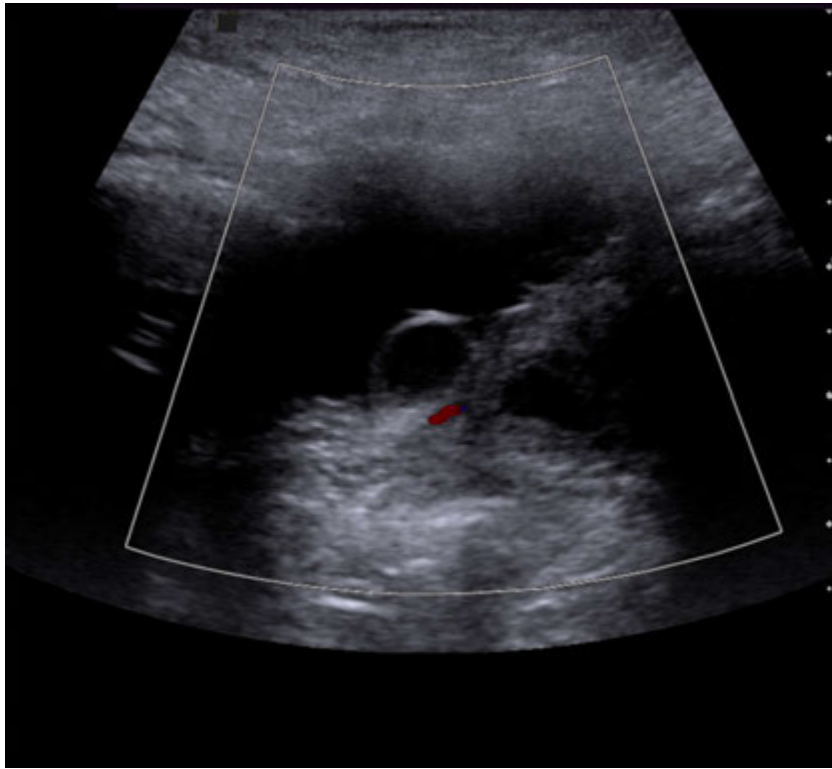


Figure 2.

Left ureterocele membrane visualized on a transverse view of the bladder on US, from the personal library of Chad Crigger, with patient permission.

Long-term outcomes for PBS survivors have improved markedly with advances in surgical techniques. Total abdominal wall reconstruction offers durable support and cosmetic benefits, with series reporting preserved renal function in 60–70% of patients at 10 years postoperatively [28]. In cryptorchid males, Fowler–Stephens orchiopexy yields acceptable testicular viability, though long-term fertility data remain limited [29]. Overall quality-of-life assessments reveal that, despite residual urological and abdominal issues, most patients achieve independence and normal schooling, highlighting the value of early multidisciplinary care [30].

3.3 Duplex collecting systems and ectopic ureters

Duplex collecting systems represent one of the most common congenital anomalies of the upper urinary tract, occurring in approximately 1 in 125 individuals and demonstrating a female preponderance [31]. Embryologically, incomplete or complete ureteral bud duplication arises from early bifurcation or the formation of two separate ureteric buds, respectively, leading to variable drainage patterns of the upper and lower renal moieties [32]. Complete duplications often predispose the upper pole to ureterocele formation or ectopic insertion, whereas the lower pole is at higher risk for VUR due to a more lateral and shorter intramural tunnel [33, 34].

Clinically, many duplex systems remain asymptomatic and are incidentally detected during evaluation for UTIs or prenatal hydronephrosis [35]. In infants presenting with a first febrile UTI, ultrasonography may reveal hydronephrosis, prompting further assessment with voiding cystourethrography (VCUG) to exclude reflux in the lower pole [34, 35]. Ultrasonography may also demonstrate a completely duplicated collecting system (**Figure 3**). The presence of a ureterocele or ectopic ureter is suggested by a cystic intravesical mass or persistent upper-pole dilation despite lower-pole decompression [32, 33]. Complementary modalities – including magnetic resonance urography (MRU) or contrast-enhanced computed tomography – can accurately delineate the course and insertion of ectopic ureters, especially in complex anatomy or when planning surgical intervention [32].

Ectopic ureters, defined by insertion distal to the bladder trigone (e.g., urethra, vestibule, or vagina) (**Figure 4**), occur in up to 20% of complete duplications and often present with continuous urinary dribbling in girls or recurrent UTIs in both sexes [36, 37]. In male patients, ectopic ureters draining above the external sphincter may manifest as UTIs or hydronephrosis, whereas those inserting below the sphincter can cause incontinence [36]. Ureteroceles associated with duplex systems further complicate drainage dynamics and may necessitate tailored intervention [33].

Management strategies are individualized according to renal moiety function, symptomatology, and associated anomalies. In asymptomatic patients with



Figure 3.
Left completely duplicated collecting system seen on US, from the personal library of Chad Crigger, with patient permission.



Figure 4.

Left ectopic ureter found on combined retrograde urethrogram and VCUG, inserting distal to the bladder neck in a girl with persistent incontinence after attempting to toilet train. From the personal library of Chad Crigger, with patient permission.

preserved differential function, conservative monitoring is acceptable, with serial imaging to assess for obstruction or reflux [38]. However, persistent obstruction, recurrent UTIs, or declining split renal function often warrants upper-pole heminephrectomy and ureteral reimplantation or ureteroureterostomy to preserve healthy parenchyma [39]. Reconstruction techniques must balance the risks of secondary VUR against the benefits of functional preservation [38].

Long-term outcomes after surgical reconstruction in duplex systems with ectopic ureters are consistently excellent. Antireflux reimplantation preserves renal function, minimizes VUR, and maintains continence, with negligible rates of recurrent infection or incontinence reported across cohorts [40, 41]. These findings reinforce that individualized, imaging-guided intervention tailored to moiety function achieves durable results with low morbidity.

3.4 Ureterocele

A ureterocele is a cystic dilation of the distal ureter within the bladder wall or urethra, resulting from incomplete rupture of the embryonic Chwalla membrane during the development of the urogenital sinus [42]. This anomaly often occurs in association with ureteral duplication, where the ectopic upper-pole ureter inserts into the bladder neck or urethra [43]. Ureteroceles have a postmortem incidence of 1 in 500–4,000, with a 4:1 female predominance [44, 45]. Prenatal US now detects more ureteroceles than before, though the classic presentation in an older child may include recurrent UTIs or incontinence [35, 46]. Without intervention, progressive obstruction can lead to hydronephrosis, renal scarring, and loss of upper-pole function [41].

The obstructive physiology of a ureterocele ranges from intermittent filling defects to complete distal ureteral obstruction, often complicated by high-grade VUR into the contralateral moiety [33]. Lower-tract symptoms may include frequency, urgency, and dysfunctional voiding, particularly when the ureterocele prolapses into the bladder neck or urethra.

Initial evaluation with renal and bladder ultrasonography typically reveals a round, cystic structure at the vesicoureteral junction, often accompanied by ipsilateral hydroureteronephrosis (**Figure 2**) [35, 43]. VCUG is essential for assessing concurrent VUR and characterizing ureterocele prolapse during micturition [47]. Diuretic renal scintigraphy further delineates split renal function, guiding the decision between upper-pole preservation and resection [48].

Endoscopic puncture or incision remains the first-line intervention for intravesical ureteroceles, with an initial radiographic decompression success rate of approximately 82%, but overall reoperation rates reach nearly 30%, especially in ectopic and duplex-system variants [46]. Upper-tract approaches – most commonly heminephroureterectomy for a poorly functioning upper pole – yield durable outcomes; in one single-center series, only 5% of children required additional surgery within five years of heminephrectomy [49]. Contemporary, algorithm-driven reviews advocate for a tailored, staged strategy (combining endoscopic decompression with open reconstruction as needed), which potentially reduces long-term reintervention rates to below 15% at 10 years [50].

3.5 Vesicoureteral reflux

Vesicoureteral reflux is the retrograde flow of urine from the bladder to the upper urinary tract, leading to pathophysiological changes that predispose individuals to a higher risk of UTIs due to the facilitation of the upward spread of bacteria [51]. Repeated episodes of pyelonephritis, coupled with increased hydrostatic pressure, can lead to irreversible renal scarring, impairing nephron function [52].

Normally, the ureterovesical junction (UVJ) has an oblique entry of the ureter into the bladder, creating a submucosal tunnel and a physiological “valve” mechanism [53, 54]. As urine fills the bladder, compression of the submucosal ureter prevents the retrograde movement of urine. On the other hand, VUR usually results from abnormal development of the UVJ. This condition is congenital and present at birth, termed primary VUR, but it is not always diagnosed immediately [55]. There is incomplete development of the intramural segment of the ureter, leading to a failure of the “flap-valve” mechanism that prevents urine from refluxing. VUR can also develop from secondary causes and present later in childhood or even adulthood due to conditions that increase intravesical pressure, including PUVs, neurogenic bladder, or other structural abnormalities.

While the incidence of VUR in a normal child is thought to be very low, there is a 30–40% incidence of VUR in patients undergoing febrile UTI evaluation, with rates decreasing as the patient becomes older [56, 57]. VUR is more commonly found in females, and there is an increased risk of VUR in patients who have siblings with the same condition. The risk of UTI and the vicious cycle with renal function is not uniform across all VUR patients. The natural history is variable, ranging from resolution to end-stage renal disease (ESRD). A lower grade of reflux and young male infants are more likely to have spontaneous resolution of this pathophysiology [58]. Factors such as the grade of reflux, concomitant bladder bowel dysfunction



Figure 5. Patient with VUR and a history of BE on intraoperative VCUG, from the personal library of Chad Crigger, with patient permission.

(BBD), and female sex increase the risk of recurrent and breakthrough febrile UTIs [59]. As expected, severe reflux and frequent UTIs are the primary contributing factors in the development and persistence of renal scarring.

The gold standard for the diagnosis and risk stratification of VUR is a voiding cystourethrogram (VCUG) (**Figure 5**), an imaging technique in which contrast material is instilled through a catheter into the bladder, followed by a series of X-rays during filling and voiding to detect reflux [60]. The International Grading System (1–5) is based on findings from this study and assists in the stratification of risk. Furthermore, as patients with reflux are at higher risk of renal scarring, a dimercaptosuccinic acid (DMSA) scan is used in the evaluation of this feature in VUR and assesses differential renal function [61]. Renal and bladder ultrasonography also plays a role in easily accessible surveillance

imaging; children with a history of VUR should receive an US to quantify renal growth, assess dilation of the collecting system, and determine bladder morphology. Formal urodynamics should only be pursued if there is VUR secondary to neurovesical dysfunction to discern detrusor sphincter dyssynergia (DSD) or hypercontractility [62].

While the utility of chronic antibiotic prophylaxis (CAP) is an active topic of debate, it remains the cornerstone of reducing UTI risk in patients with VUR, along with good hydration, hygiene, and bowel regimen. The AUA Pediatric Vesicoureteral Reflux Guidelines Panel recommends CAP for children under a year of age with a history of febrile UTI or Grades 3–5 VUR. Furthermore, patients with comorbid BBD may be at increased risk of recurrent UTI; thus, antibiotics are indicated in this subpopulation [63, 64]. However, even with CAP, some children may experience severe UTIs and persistent reflux that endanger renal function [65]. While shared decision-making is paramount, anti-reflux surgery is recommended for those with progressive renal injury, renal atrophy, persistent pyelonephritis, or noncompliance with CAP. The most common approach is ureteral reimplantation, which yields high rates of success, even achieving 80.7% resolution of Grade 5 VUR [66]. Another approach for mild-to-moderate VUR is endoscopic injection of a bulking agent, although recurrence rates may be higher than those of open or robotic ureteral reimplantation [67].

3.6 Posterior urethral valve

Posterior urethral valve is a congenital anomaly in which leaflets of tissue impede the flow of urine through the urethra, causing bladder outlet obstruction [68]. This anomaly occurs only in male infants and is estimated to affect 1–2 per 10,000 live births [69–71]. PUV can be diagnosed either ante- or postnatally. The condition poses a high risk for renal injury, with 20–65% of affected patients developing CKD and 8–21% progressing to ESRD during childhood [72, 73]. Increased residual volumes from obstruction cause elevated voiding pressures that are transmitted to the renal pelvis and upper tracts, leading to renal tubular damage and impaired concentrating ability. The resulting polyuria further perpetuates the pathology of the urinary system. When in utero, prolonged renal dysfunction can cause decreased urine output, leading to uropathy-associated pulmonary hypoplasia (Potter's syndrome) [74]. As with VUR, there is a spectrum of disease in PUV. Age at diagnosis has not been universally associated with outcomes; nadir serum creatinine within the first year of life is the primary biomarker predictive of future risk of ESRD [75, 76].

The incomplete emptying and backup of urine in PUV can create a favorable environment for bacterial growth, predisposing individuals to the risk of UTIs. VUR is present in up to 60% of children with PUV at the time of diagnosis, as high bladder pressures are transmitted to the upper urinary tract [77, 78]. This comorbid condition increases the risk of UTIs, particularly when VUR is high grade and bilateral. The comorbid VUR cohort has a higher risk of renal injury and recurrent UTIs; the presence of bilateral VUR in PUV is an independent risk factor for long-term poor renal prognosis [79, 80]. It was previously believed that unilateral VUR with preserved contralateral renal function was associated with a “pop-off” mechanism that improved long-term outcomes, although this has been found not to be the case [81, 82].



Figure 6.

Oblique view of VCUG showing an elongated posterior urethra and an irregularly shaped bladder consistent with PUV. From the personal library of Chad Crigger, with patient permission.

Prenatally, PUV appears as a thickened, distended bladder on US with a dilated posterior urethra. This ultrasonographic finding is coined the “keyhole sign” [83]. During the gestational period, PUV falls under the umbrella term of lower urinary tract obstruction. PUV is confirmed in the neonatal stage with cystoscopy and VCUG. On fluoroscopy, a dilated posterior urethra is pathognomonic for PUV and is often found in conjunction with a trabeculated bladder and VUR (**Figure 6**). Annual testing is recommended for patients with PUV, and a formal urodynamics study can be conducted when there is worsening of UTIs, upper tract dilation, or bladder function [84].

Imminent surgical intervention is the primary management strategy to alleviate the structural cause of bladder obstruction. In the meantime, catheter placement is paramount to drain the bladder, often coupled with the initiation of a prophylactic antibiotic to prevent catheter-associated urinary tract infection (CAUTI) while the diagnostic process is ongoing [85]. Serum creatinine, a prognostic biomarker, should also be monitored prior to surgery. The primary obstacle to choosing a surgical procedure is the size of the urethra. While transurethral resection of the urethral valve (TURV) is preferred, PUV is often comorbid with preterm status, which complicates the selection of an intervention [86]. This is discussed further in the *Surgical and Interventional Complexities* section of the chapter. Even after the relief of the physical bladder obstruction, bladder cycling in PUV infants is not normal; anticholinergic medication can be utilized in those with persistent bladder hypercontractility and poor compliance. While anticholinergics help resolve VUR

and hydronephrosis, they have not been associated with a change in UTI rates [87]. Additionally, although usually not required in the first years of life, clean intermittent catheterization (CIC) can be considered in those with persistent bladder dysfunction and recurrent UTIs. Furthermore, circumcision in infants with PUV has been shown to reduce the incidence of UTIs by 83% [88]. In those who progress to renal failure, the lower urinary tract should be optimized to prepare for renal transplantation.

3.7 Bladder exstrophy–epispadias complex

There is a wide spectrum of presentations for BE, ranging from classic BE without other organ involvement to cloacal exstrophy. Classic BE is present in 1 per 50,000 live births and is more common in males [89, 90]. Cloacal exstrophy is about six times rarer [91]. The pathogenesis of BE is not fully understood, but it is believed that there is an anomaly in embryogenesis, implicating disruption of the cloacal membrane [92]. Concurrent features often include epispadias (in males), hemi-clitoris (in females), and pubic diastasis (**Figure 7**).

There is an elevated risk of UTI at multiple points during the life course of individuals with BE. After birth, the bladder and urethra are closed. At this time, tubes, stents, and drains are placed to ensure proper healing and urine drainage. These devices introduce a risk of bacterial contamination and infection, notably catheter-associated urinary tract infection (CAUTI). However, this risk is reduced with perioperative and postoperative antibiotics [93]. With primary (at birth) repair, the bladder can cycle and begin to grow, ultimately reducing the risk of compromising the upper urinary tract. However, VUR, a risk factor for UTI, still develops in virtually all patients due to ureters that insert onto the bladder plate with



Figure 7.
Classic BE in a male, from the personal library of Chad Crigger, with patient permission.

a minimal submucosal tunnel [94]. While this resolves in many, VUR can also be persistent. In the setting of BE, VUR is managed as in Section 3.5. Poor bladder compliance or outlet obstruction can predispose individuals to urinary stasis, a risk factor for infection. Similar to spina bifida, older children with BE may also undergo bladder augmentation in the setting of low bladder compliance [95, 96]. This procedure can lead to the formation of bladder stones, which harbor bacteria and make infections more difficult to treat. To prevent chronic UTIs, these stones often must be removed surgically.

Bladder exstrophy can potentially be diagnosed in-utero by US, where there is an absence of the fluid-filled bladder within the pelvis [97, 98]. Other features, such as iliac crest widening, may also be noted on imaging. Unlike PUV, there is no association with oligohydramnios. Postnatally, the infant should receive a renal and bladder US, which may influence UTI management, as well as a pelvic X-ray. In the most severe presentation of BE, cloacal exstrophy, a spinal US should also be completed, as there is an association with spinal dysraphism, which further places the infant at risk of UTI [99]. Newborns should be monitored for symptoms of UTI due to the exposed bladder plate and abnormal anatomy. If necessary, urinalysis and urine culture can be performed from clean-catch urine, as straight catheterization is not possible in this population.

As with other congenital conditions, the surgical management of BE has evolved over time and is still debated. Primary repair for exstrophy is performed in the immediate newborn period, within 72 hours [100]. Those who prefer this method argue that the bladder is potentially exposed to fewer external noxious stimuli and may preserve bladder cycling. This can be performed with or without an iliac osteotomy. The alternative technique is delayed closure at a later age, which may be preferable due to reduced safety concerns surrounding anesthetic, improved renal function, and increased parent-child bonding [101]. Exact surgical techniques will be discussed in the *Surgical and Interventional Complexities* section. When comparing primary versus delayed closure, there are no differences in continence rates and ultimate bladder capacities [102]. When observing UTI-specific complications in the 30-day postoperative period, 2% of the delayed cohort developed pyelonephritis compared to 8.4% of the primary cohort [103]. Another single-site cohort study demonstrated a higher rate of long-term, recurrent UTIs in the delayed closure cohort [104]. However, the consensus is that although the BE population is at elevated risk of UTIs compared to the general population, there is no strong evidence suggesting an increased risk of UTIs with surgical timing.

3.8 Neurogenic bladder (e.g., myelomeningocele, tethered cord)

Along with PUV, neurogenic bladder is perhaps the most common condition for which a regimen to prevent recurrent UTIs and resulting upper tract damage is emphasized [105, 106]. Neurogenic bladder results from multiple pediatric conditions, including neural tube defects such as myelomeningocele, sacral agenesis, and tethered cord [107]. While these conditions have distinct pathophysiological mechanisms, the principles of neurogenic bladder management are broadly applicable across etiologies.

The most common cause of pediatric neurogenic bladder is spina bifida, which occurs in 3.5 out of 10,000 live births [108]. Risk factors for this condition

include folic acid deficiency, siblings with neural tube defects, and extreme maternal age. There is a disruption of the neural signaling between the bladder and brain, with the nerves coordinating bladder storage and emptying being disrupted or absent. As a result, there are multiple patterns of neurogenic bladder; severity is variable, and the level of the lesion does not correlate well with bladder function [109]. Patients may not completely empty their bladder, leak involuntarily, or have absent sensation of bladder emptying. There is often a lack of coordination between the detrusor muscle and the sphincter controlling urine outflow, a condition termed DSD. Although there is no mechanical obstruction like that observed in PUV, there is a similarly high-pressure environment that endangers the upper urinary tract and places the patient at higher risk of UTIs.

As the diagnosis, surveillance, and treatment of neurogenic bladder are highly complex, the course of urological involvement should be explained to families early. Newborns with conditions associated with neurogenic bladder should undergo an US of the bladder and kidneys after 48 hours of life [110, 111]. Additionally, the timing of primary neurosurgical repair has a significant impact on neurogenic bladder prognosis [112]. Most newborns will have normal anatomy, and many will be able to void, complicating initial management. The initiation of CIC varies by institution [113]. Some institutions take a proactive approach, initiating all newborns on CIC and continuing treatment regardless of low residual volumes. In this same approach, an early voiding cystourethrogram (VCUG) will be obtained to assess urinary dynamics. Other institutions are solely reactive, only initiating CIC if bladder residuals are high. While there was initial concern that CIC elevated the risk for UTI, recent studies have not shown an association. In infants with trabeculated, thick bladders, Grade 5 VUR, or moderate-to-severe hydronephrosis, there is strong evidence to continue CIC to prevent upper tract damage [114]. After birth, patients are seen again around 2–4 months of age for repeat US and urodynamic studies. Bladder trabeculations, VUR, detrusor leak point pressure >40 cm, and DSD have been associated with an increased risk of developing UTIs. If these findings are observed, CIC every four hours and oxybutynin, an anticholinergic, can be initiated, although protocols vary based on the institution. Antibiotic prophylaxis is not recommended solely for chronic CIC; however, if a patient has comorbid VUR, prophylaxis should be considered.

Even with CIC and anticholinergics, some patients may experience recurrent UTIs and upper tract deterioration. In this situation, vesicostomy should be considered [115]. This surgical intervention constantly diverts urine from the bladder through a stoma, protecting the upper tract. However, this is a temporary measure, and as the patient grows, other surgical procedures can be considered, depending on whether conservative management fails or the patient desires continence. Bladder augmentation increases bladder capacity and reduces pressure. For children unable or unwilling to catheterize via the urethra, the creation of a continent catheterizable channel (Mitrofanoff) can improve quality of life. For those with sphincter incompetence, resistance is increased at the bladder neck through bladder neck reconstruction [116]. Surgical innovation in this area is ongoing and individualized based on a child's anatomy, degree of continence, and family preference, with the overarching goal of preserving kidney function and optimizing UTI prevention.

3.9 Renal aplastic dysplasia

Renal aplasia/agenesis and hypodysplasia/dysplasia (the “renal aplasia–dysplasia” spectrum) result from failed or abnormal ureteric-bud induction of the metanephric mesenchyme, leading to absent or dysplastic nephrons. Multicystic dysplastic kidney (MCDK) lies at the cystic end of this spectrum. Pathogenic variants are increasingly recognized across key developmental pathways (e.g., HNF1B, PAX2, EYA1, GREB1L, DSTYK) and justify targeted testing when bilateral disease, syndromic features, or a family history is present [5, 117].

Unilateral renal agenesis (URA) and unilateral MCDK are common causes of a congenital solitary functioning kidney (SFK). In European surveillance, URA averages approximately 3–4 per 10,000 live births, and bilateral renal agenesis occurs in approximately 1–2 per 10,000 births, while MCDK is observed in approximately 4.1 per 10,000 births across 12 European countries [118]. Most infants are asymptomatic and are identified through prenatal or early postnatal US; bilateral agenesis is uniformly fatal due to severe oligohydramnios and pulmonary hypoplasia. The long-term risk in SFK centers on hyperfiltration injury, with the development of hypertension, proteinuria, and CKD in a subset [119].

Because mesonephric (Wolffian) and paramesonephric (Müllerian) structures develop in concert with the metanephros, cross-system associations are frequent. In males, Wolffian duct anomalies, such as seminal vesicle cysts, ejaculatory duct obstruction, and vasal defects, may accompany ipsilateral renal agenesis – the classic Zinner syndrome triad [120]. Ectopic ureters may insert into the seminal vesicle or ejaculatory duct, causing painful ejaculation, recurrent epididymo-orchitis, hematospermia, obstructive azoospermia, or subfertility in adolescents and young adults. Pelvic MRI best delineates seminal-tract anatomy [121]. In females, Müllerian anomalies are common in girls with URA/MCDK/SFK (e.g., uterine didelphys, hemi-uterus, transverse or longitudinal vaginal septa, MRKH spectrum) [122, 123]. Early pelvic US (late childhood/early adolescence) is recommended to prevent complications of obstructive anomalies (dysmenorrhea, hematometra, endometriosis) and to coordinate gynecologic care [118].

Newborns with unilateral disease are typically well, with an incidental nonfunctioning kidney (MCDK or URA). Recurrent UTIs are more likely if contralateral CAKUT (e.g., VUR, UPJ obstruction) coexist. Older boys with Wolffian-tract anomalies may present with pelvic/perineal pain, postejaculatory pain, or infertility; girls with obstructive Müllerian anomalies may have cyclic pelvic pain at menarche [120].

The renal/SFK core work-up includes postnatal renal and bladder US to confirm the diagnosis, document compensatory hypertrophy, and detect additional CAKUT, baseline blood pressure and urinalysis/albuminuria with periodic reassessment thereafter. VCUG is reserved for hydronephrosis, UTI, or bladder abnormalities. Genetic testing is considered if bilateral disease, extrarenal anomalies, or a family history is present [119]. Targeted genital-tract imaging is guided by risk and symptoms: Boys with SFK and pelvic symptoms, abnormal semen parameters, or recurrent epididymal infections should undergo pelvic MRI ($\pm$ transrectal US) to evaluate seminal vesicles and ejaculatory ducts, and girls with SFK (URA/MCDK) should have a screening pelvic US before menarche to identify Müllerian anomalies and plan timely gynecologic management [120, 122].

Unilateral MCDK is managed nonoperatively in most cases; nephrectomy is rarely indicated and is reserved for cases involving mass effect, diagnostic uncertainty, or refractory hypertension. Meta-analytic data show low risks of hypertension (~3%) and malignancy (~0.07%, largely Wilms tumor), and prophylactic nephrectomy is not indicated [124]. For congenital SFK due to URA or MCDK, care is risk-stratified and lifelong: low risk (SFK with compensatory hypertrophy), medium risk (no compensatory growth and/or additional CAKUT), and high risk (reduced eGFR and/or proteinuria and/or hypertension) categories guide visit cadence and testing. Counseling should emphasize kidney-protective habits (normal sports participation, avoiding excess salt/protein, prompt UTI evaluation), and renin–angiotensin system blockade should be initiated for proteinuria or hypertension [119]. Male Wolffian-tract anomalies within the Zinner spectrum are treated based on symptoms and obstruction, with options including transurethral unroofing of ejaculatory duct cysts and laparoscopic/robotic excision of symptomatic seminal vesicle cysts or ectopic ureteral remnants, and appropriate fertility counseling is recommended [120]. Female Müllerian anomalies are managed per pediatric/adolescent gynecology standards, such as resection of obstructing vaginal septa to prevent retrograde menstruation and endometriosis, with tailored fertility counseling depending on uterine anatomy or MRKH spectrum [118, 123].

Most children with unilateral renal aplasia/dysplasia and a healthy contralateral kidney achieve normal growth with kidney-protective care; nonetheless, a subset develops hypertension, proteinuria, and CKD – supporting annual blood pressure assessment and urinalysis through adolescence and adulthood, with periodic eGFR checks per risk tier [119].

A consolidated summary of the epidemiology, clinical features, and management strategies for the major congenital anomalies discussed above is provided in **Table 1** for reference.

4. Cross-cutting diagnostic considerations

Accurate diagnosis of pediatric congenital urologic anomalies relies on a multimodal approach that integrates advanced imaging techniques, functional assessments, and biochemical markers. Early and precise identification of structural abnormalities, lower urinary tract dysfunction, and renal impairment is essential to guide timely intervention and optimize long-term outcomes. This section outlines key considerations across three domains – imaging, urodynamics, and biomarkers/laboratory tests – emphasizing their complementary roles in comprehensive evaluation.

4.1 Imaging modalities

Ultrasound remains the first-line screening tool for congenital uropathies due to its wide availability, lack of ionizing radiation, and ability to characterize hydronephrosis and duplex systems [125, 126]. When further anatomical delineation is required – particularly for complex collecting system anomalies, ectopic ureters, or vascular variants –MRU provides excellent soft-tissue contrast and functional information without radiation exposure [15, 32]. Comparative studies demonstrate that static and excretory MRU yields equivalent or superior anatomic detail to MAG3

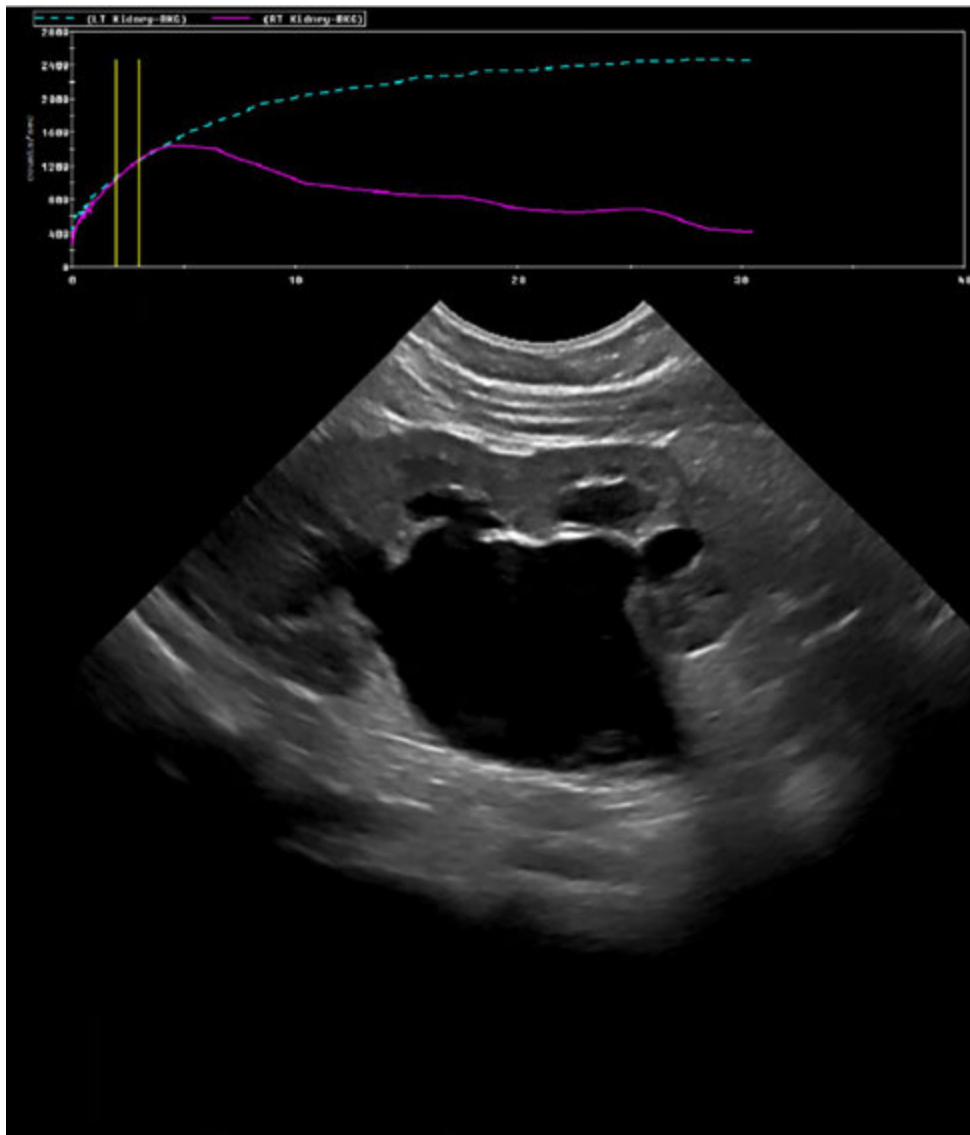


Figure 8. Drainage curves of MAG-3 indicating a UPJO of the left kidney (blue dashed line), with T1/2 not appreciated due to high-grade obstruction, as confirmed by ultrasound imaging.

scintigraphy (**Figure 8**) and can concurrently assess renal morphology, ureteral course, and differential renal function in a single examination [127].

4.2 Urodynamic evaluation

In children with suspected neurogenic bladder or outlet obstruction, formal urodynamic studies – including pressure-flow analysis and video-urodynamics – offer an objective assessment of bladder storage and voiding function. Foundational pediatric urodynamic protocols outline standardized filling and voiding phases to

quantify detrusor compliance, leak point pressure, and postvoid residuals [107]. Recent consensus guidelines from the EAU/ESPU recommend urodynamics in all children with myelomeningocele, PUVs, or other neurologic lesions to stratify risk for upper tract deterioration and inform conservative versus surgical management [114]. Moreover, the integration of noninvasive measures (e.g., bladder wall thickness on US) may further refine patient selection for invasive testing [110, 114].

4.3 Biomarkers and laboratory assessment

Serum creatinine and cystatin C serve as primary indicators of glomerular filtration in infants and children, but interpretation must account for age-related maturation and muscle mass variability [75, 128]. Nadir creatinine – defined as the lowest serum creatinine within the first year of life in patients with PUVs – correlates strongly with long-term renal outcomes and thus informs the timing of definitive intervention [76]. Cystatin C, unaffected by muscle mass, offers improved early detection of mild renal impairment and has been incorporated into pediatric reference equations to enhance sensitivity for subclinical CKD [128].

Collectively, these diagnostic modalities form an integrated framework that balances sensitivity, specificity, and safety. By tailoring the choice and sequence of imaging, functional testing, and laboratory markers to individual patient risk profiles, clinicians can achieve timely diagnoses, minimize invasive procedures, and improve prognostic stratification in congenital urologic disorders.

5. Surgical and interventional complexities

In children with congenital anomalies, surgical intervention is often warranted to prevent upper tract damage and recurrent UTIs. Within each specific condition, there is nuanced consideration of timing and surgical approach. In this section, we discuss disease-specific technical nuances, highlight the approach to intraoperative discovery of concomitant anomalies, and discuss how the advent of minimally invasive techniques has changed the landscape of care.

The urinary obstruction in PUV is relieved surgically, either through primary valve ablation (PVA) or vesicostomy. PVA is the preferred intervention, given the reduced surgical morbidity and noninferiority to vesicostomy [129, 130]. PVA is also believed to allow for physiologic bladder cycling and more natural voiding compared to vesicostomy. In premature infants who are unable to accommodate the pediatric cystoscope, PVA may not be feasible. However, advances in surgical techniques, especially through a catheter dilation regimen, have widened the eligibility for PVA, achieving a 97% success rate in a single-institution PUV cohort. Vesicostomy does not necessarily increase UTI risk compared to PVA, as the reduction of UTI incidence is determined by relieving obstruction [131]. However, for those with a severe initial presentation, such as recurrent febrile UTIs or renal compromise, vesicostomy provides rapid drainage and reduces the risk of additional UTIs until definitive treatment [84]. Overall, it is important to note that regardless of the selected treatment, postoperative UTIs remain very common and must be monitored.

Minimally invasive surgery, including abdominal laparoscopy and robotic-assisted surgery, has advanced surgical procedures in the realm of pediatric urology. Modifications in surgical technique can be understood in their application to

addressing ureteropelvic junction obstruction (UPJO) through pyeloplasty. From 2003 to 2015, 85% of all infant pyeloplasties were accomplished using the open technique [132]. However, in the last decade, there has been a marked adoption of minimally invasive techniques across all ages, ranging from adolescents to infants. Laparoscopic surgery has been shown to reduce the length of hospital stay with similar analgesic use compared to open surgery [133]. Although there is no difference in success rates, pediatric patients who undergo robotic-assisted procedures experience reduced hospital stays and lower use of pain medication compared to laparoscopic or open techniques [134]. Postoperatively, rates of UTI approach 35% and can impact outcomes, such as increasing the risk of re-obstruction [135]. Risk factors include indwelling stents, lower BMI, age under 19 months, and male gender [136]. Rates of UTI are comparable among techniques [137]. In a series of 185 children undergoing robotic-assisted pyeloplasty at a tertiary care center, only 3 (1.6%) developed a postoperative UTI. As robotic systems continue to evolve and provide superior surgical precision, it is likely that this technique will be further adopted without concern for increased infection rates. However, there remain contraindications, including very low body weight, prior complex intra-abdominal operations, or other structural anomalies [138, 139].

While the basics of surgical timing in BE were discussed previously, it is important to address innovations in surgical management and their corresponding infection risks. The modern staged repair of exstrophy includes three stages: closure of the bladder at birth, epispadias repair at 6–12 months, and bladder neck reconstruction with bilateral ureteral reimplantation at 4–5 years. The complete primary repair of BE involves the combination of bladder closure and epispadias repair in a single operation; bilateral ureteral reimplantation may be performed at the same time to achieve urinary continence. Given the complexity of such surgical interventions, complications can be common. Beyond dehiscence and ischemia, a urethrocutaneous fistula can form, for which a suprapubic tube should be placed for continuous urinary diversion. UTIs are very common after BE closure. However, rates between staged repair and complete primary repair are similar, even though staged repair presents repeated opportunities for infection due to multiple procedures over time [140]. Due to comorbid VUR and baseline elevated UTI risk, BE patients are at risk of recurrent UTIs and pyelonephritis [141]. Regardless of the surgical approach, infection prevention remains a core principle of BE management, with ongoing assessment of renal function and antibiotic use.

6. Postoperative care and long-term follow-up

The postoperative and long-term management of patients with congenital genitourinary anomalies is paramount to preserving renal function and preventing recurrent UTIs through bladder rehabilitation. The two main pillars of this program are CIC and anticholinergic therapy. CIC is a cornerstone of spina bifida management and is typically initiated within days of birth [142]. While the exact regimen varies from institution to institution, newborns are typically started on CIC every 3–4 hours using a 6–8 French catheter, with adjustments as the bladder grows, aiming to keep volumes under 400–500cc to prevent overdistention. Urodynamic studies and USs are indicated every 6–12 months to further assess bladder and kidney health. As this bladder care is lifelong, patients and their families should be counseled

early on the importance of maintaining a catheter regimen and maintaining close correspondence with a multidisciplinary healthcare team. Independence should also be emphasized, as patients can typically handle self-catheterization independently around 8–10 years of age. This also helps prepare them for postoperative management of self-catheterizable channels. In children with refractory urinary incontinence, neurogenic bladder, or detrusor overactivity, anticholinergic agents are considered the first-line pharmacotherapy. Several agents are available, with oxybutynin being the most commonly used. In refractory cases, the dosing of a single agent can be increased, or a combination of two anticholinergics can be considered [143]. Intravesical instillation of these agents can also be considered for those experiencing severe side effects [144]. Patients should be monitored for signs of side effects, such as dry mouth and constipation, and dosing should be adjusted as necessary.

Continence outcomes should be regularly assessed using a combination of measurement tools. Patient-reported outcomes include voiding and CIC diaries. Objective data can be collected through urodynamic studies, US, and postvoid urine measurements. Especially in patients with a surgical history, it is important to monitor for complications such as strictures and fistulas; regular postoperative visits enable early identification of issues. Renal function should also be strictly monitored, as one of the most devastating effects of the discussed congenital conditions is the need for RRT. Function can be regularly assessed by cystatin C, renal US, and VCUG if there is concern for reflux [128]. In patients with recurrent febrile UTIs, a DMSA scan should be performed to assess for segmental scarring. Due to the inter-relationship between the kidney and hypertension, regular blood-pressure monitoring is critical [145]. Comprehensive care also includes addressing psychosocial challenges. Children and adolescents with persistent urinary symptoms are at higher risk of anxiety and low self-esteem [146, 147]. Furthermore, invasive procedures can be acutely traumatic. Parents often also experience stress and anxiety due to the demands of medical management. Early and ongoing psychological support is recommended for patients and families to help manage the emotional impact and develop coping strategies.

As patients with genitourinary anomalies requiring lifelong monitoring approach adulthood, there are many questions about care, documentation handover, and multidisciplinary engagement. Transitional urology is a specialized field that focuses on guiding young adults as they move from pediatric to adult care [148]. Securing a smooth transition helps minimize long-term surgical complications, preserve renal function, and address components of quality of life, including sexuality and fertility. A successful transition requires collaboration among urologists, nephrologists, psychologists, and other specialists. Preparation should begin in early adolescence and involve open conversations with written transition plans. As transitional urology continues to develop, there is less concern about gaps in care that previously resulted from the limited experience of adult urology providers with complex congenital conditions.

Across congenital genitourinary anomalies, UTI prevention and renal preservation remain central pillars of management. Despite these shared clinical goals, there exists significant variability in diagnostic pathways, risk stratification, and postoperative surveillance. This heterogeneity underscores an urgent need for multi-institutional collaboration to define evidence-based protocols and improve long-term outcomes. Multicenter registries and longitudinal cohorts should be implemented to track outcomes, with emphasis on UTI incidence, renal function

trajectory, and quality of life. Psychosocial metrics and transitional care readiness should be integrated into routine outcome evaluation. The goal of continuously improving care for these patients must be achieved through aligned, multidisciplinary efforts.

7. Conclusions

Pediatric CAKUT encompass a diverse array of pathologies – ranging from obstructive lesions such as UPJO and PUVs to refluxogenic conditions such as VUR and complex structural defects including ureteroceles, duplex systems, bladder exstrophy–epispadias complex, and neurogenic bladder. Each entity carries its own spectrum of dysfunction, from progressive renal scarring and hypertension to recurrent UTIs and bladder compliance abnormalities. Despite advances in prenatal imaging, minimally invasive surgery, and bladder rehabilitation strategies, long-term preservation of renal function and prevention of infection remain the paramount goals across all disease categories.

Achieving optimal outcomes demands a truly multidisciplinary approach. Urologists, nephrologists, radiologists, geneticists, bioengineers, and rehabilitation specialists must collaborate from the time of prenatal diagnosis through adult transition to integrate anatomic correction, functional assessment, and innovative therapies. Early involvement of nursing, psychology, and social work teams ensures that families are supported through complex care regimens – such as CIC, anticholinergic management, and self-catheterizable channel education – while research partners work in tandem to refine surgical techniques and explore regenerative medicine avenues.

Looking forward, coordinated efforts are needed to standardize diagnostic pathways, surgical indications, and follow-up protocols through multi-institutional registries and prospective cohorts. By uniting around common data elements – covering UTI incidence, renal function trajectories, psychosocial outcomes, and transitional care metrics – clinicians and investigators can define evidence-based guidelines and accelerate the translation of emerging technologies into practice. Such collaborative frameworks promise not only to elevate the quality of care for children with congenital uropathies but also to generate the high-impact science that will shape the next generation of personalized therapies.

Abbreviations and acronyms

UPJO	Ureteropelvic junction obstruction
PUV	Posterior urethral valve(s)
VUR	Vesicoureteral reflux
UTI	Urinary tract infection
UDS	Urodynamic study
MRU	Magnetic resonance urography
CIC	Clean intermittent catheterization
EEC	Exstrophy–epispadias complex
SFU	Society for fetal urology (hydronephrosis grading)
BBD	Bladder bowel dysfunction

Classification systems

A: SFU hydronephrosis grading

Grade 0: No dilatation

Grade 1: Pelvic dilatation only

Grade 2: Pelvic and calyceal dilatation without cortical thinning

Grade 3: Pelvic and calyceal dilatation with mild cortical thinning

Grade 4: Severe calyceal dilatation with significant cortical thinning

International Children's Continence Society (ICCS) terminology

Overactive bladder: urinary urgency $\pm$ frequency, with or without incontinence

Underactive bladder: diminished detrusor contractility, prolonged voiding

Neurogenic bladder: detrusor and/or sphincter dysfunction due to a neurologic lesion

Conflict of interest

The authors declare no conflict of interests.

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Chapter 2

Urogenital Fistulas

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Abstract

Urogenital fistulas are pathological communications between the urinary and genital tracts that result in continuous leakage of urine and significant morbidity. Their occurrence reflects distinct etiological patterns worldwide: While obstetric trauma remains the leading cause in low-resource settings, most cases in developed regions are iatrogenic, following gynecologic, urologic, or oncologic procedures. Clinical manifestations depend on the fistula's location and size, ranging from persistent incontinence to cyclic hematuria or flank pain in ureteral involvement. Diagnosis requires targeted examination, dye testing, and imaging to delineate the tract and assess surrounding tissue quality. Surgical repair remains the primary treatment, with transvaginal access preferred for low vesicovaginal fistulas and abdominal, laparoscopic, or robotic approaches used for complex or high-lying defects. Interposition of vascularized tissue, such as a Martius or omental flap, may be indicated in radiated or recurrent cases. Although contemporary minimally invasive techniques have improved success rates, radiation-induced fistulas continue to present reconstructive challenges. Prevention through timely obstetric care, intraoperative identification of urinary injuries, and adherence to reconstructive principles remains crucial. This chapter addresses epidemiology, pathophysiology, diagnostic strategies, operative techniques, and preventive measures in the management of urogenital fistulas.

Keywords: fistula, obstetric labor complications, radiation injuries, reconstructive urology, fistula repair, Martius flap

1. Introduction

Urogenital fistulas are abnormal communications between the urinary tract and the genital tract. They typically present with continuous urinary leakage, recurrent urinary tract infections, and significant impairment of quality of life.

The term “fistula” originates from Latin, meaning a pipe or tube – a hollow channel for fluid or air. This ancient word, evoking a narrow conduit, entered medical language to describe an unwanted passage between body parts that were never meant to communicate. The term has appeared in medical texts since antiquity to describe unnatural internal openings (often resulting from chronic infection or trauma). The modern usage of “fistula” (formerly “ruptura”) was introduced in 1597 by Spanish physician Luis de Mercado. The word has remained consistent across languages – “fistule” in French and “Fistel” in German – all

harking back to the Latin imagery of a tube. This historical continuity underscores the persistent challenge fistulas have posed to medicine, from the writings of Hippocrates to the present day.

2. Epidemiology

2.1 Developing countries

Globally, an estimated 2–3 million women live with untreated obstetric fistulas [1]. The prevalence of urogenital fistulas varies by region. Such fistulas are rare in Europe and North America but common in parts of Africa, India, and Southeast Asia, primarily due to obstetric causes. For example, in Nigeria, one fistula occurs per approximately 288 deliveries, most often from prolonged obstructed labor with delayed emergency cesarean section [2]. Overall, obstetric fistula remains a significant public health problem in low-resource settings (pooled prevalence around 0.29 per 1,000 women; 50,000–100,000 new cases annually, mostly in sub-Saharan Africa and South Asia [3]). According to data from 20 African countries, cesarean section is performed in only 0.1–3.0% of deliveries, whereas the World Health Organization recommends a rate of at least 5% to reduce maternal morbidity and mortality [4, 5].

2.2 Developed countries

In developed regions, urogenital fistulas are much less common and are usually iatrogenic. In the United Kingdom, roughly 150 genital fistula repair procedures are performed annually. The incidence of fistula after a routine hysterectomy is about 1 in 1,300 (0.08%). Following laparoscopic or vaginal hysterectomy, the risk increases to approximately 1%. In cases of radical hysterectomy or after radiotherapy for gynecologic malignancies, fistula incidence is 1–4%. After pelvic exenteration, it can be up to 10% [6].

In developed countries, more than 70% of urogenital fistulas are complications of surgical procedures on pelvic organs. These are often referred to as “gynecological” fistulas, although urinary tract injuries may also occur after colorectal or oncologic interventions [7]. Modern obstetric care and surgical techniques have made obstetric fistulas rare in industrialized countries; iatrogenic injuries during pelvic surgery (e.g., hysterectomy) now account for the majority of cases.

3. Etiology and pathogenesis

Urogenital fistulas result from a variety of causes, including obstructed labor, surgical or obstetric trauma, radiation damage, advanced malignancy, infection, or injury to the genitourinary tract. Similar mechanisms can produce fistulas between the urinary system and gastrointestinal tract (enterourinary fistulas), especially in the context of inflammatory bowel disease.

3.1 Obstetric fistulas

Obstetric fistulas primarily arise from prolonged, obstructed labor in settings without timely surgical intervention. During obstructed labor, the fetal head becomes impacted in the maternal pelvis for an extended period. The bladder wall, urethra, and vaginal wall are compressed between the fetal skull and the bony pelvis, leading to prolonged ischemia (lack of blood flow) in the vesicovaginal septum. After sustained pressure for many hours, the compressed tissues become hypoxic, edematous, and eventually necrotic. Within several days postpartum, the devitalized tissue sloughs off, leaving a tract between the bladder and vagina (a vesicovaginal fistula (VVF)) and often between the rectum and vagina (a rectovaginal fistula (RVF)), causing continuous leakage of urine or feces. This mechanism of pressure necrosis accounts for the majority of VVFs in low-resource settings where cesarean delivery may not have been available in time [8, 9].

Not all obstetric fistulas are purely ischemic. In modern obstetric practice, direct traumatic or surgical injury can also cause fistulas. Deep vaginal lacerations from forceps or vacuum-assisted delivery, an inadvertent bladder laceration during cesarean section or postpartum hysterectomy, or a uterine rupture extending into the bladder can all lead to fistula formation if not recognized and repaired properly (**Figure 1**). Such injuries, especially in the presence of infection or devascularized tissue, may epithelialize into a fistulous tract within days to weeks after delivery [10]. In summary, obstetric fistulas are most commonly due to pressure necrosis from obstructed labor but can also result from acute birth-related injuries that go unrepaired.

3.2 Iatrogenic fistulas

In developed countries and tertiary centers, surgical injury is the leading cause of urogenital fistulas [11]. The classic scenario is an unrecognized injury to the bladder or ureter during pelvic surgery (most often a hysterectomy), resulting in a vesicovaginal or ureterovaginal fistula (UVF) a short time after the operation [12].



Figure 1.
Vesicouterine fistula (VUF) after cesarean section.

The pathogenesis usually begins with an intraoperative insult, such as a bladder laceration that is missed, a burn injury from cautery, inadvertent incorporation of the bladder or ureter into a suture ligature, or excessive dissection that compromises the blood supply. These injuries set the stage for tissue breakdown. Postoperatively, within a few days to a couple of weeks, the patient develops vaginal urine leakage once the suture line or injured area necroses and opens.

Ischemia from a tight suture can also cause fistulas. For example, an overly tight ligature or clamp on bladder tissue can cause localized necrosis that later opens into the vagina. Notably, a fistula may occur even without an obvious bladder tear during surgery – minor devascularization can silently progress to a fistula tract over time. Virtually any pelvic procedure involving the uterus, cervix, vagina, bladder, or ureters has the potential to cause a fistula if complications occur. In addition to hysterectomy, documented iatrogenic causes include anterior vaginal wall repairs, anti-incontinence sling procedures, difficult cesarean deliveries, severe episiotomy extensions, and other pelvic surgeries (**Figure 2**). The common theme is surgical injury coupled with impaired healing, especially in the presence of infection, poor perfusion, prior radiation, or pelvic abscess formation [13].

3.3 Radiation-induced fistulas

Therapeutic pelvic radiation for cancers of the cervix, uterus, bladder, or prostate is a well-recognized cause of delayed fistula formation. Radiation injury follows a distinct pathophysiology: Damage to small blood vessels and tissues leads to progressive ischemia, fibrosis, and loss of normal healing capacity. Irradiated

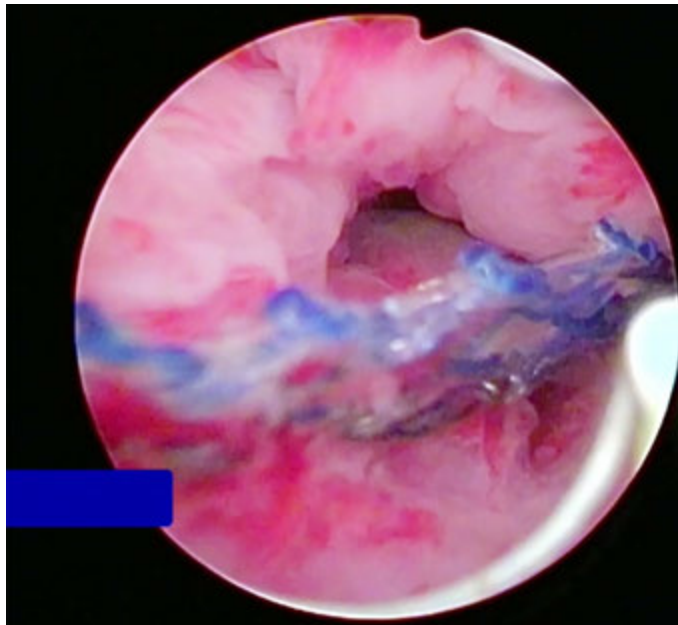


Figure 2.
Endoscopic visualization of sling erosion into the urethra.

tissues become fragile and atrophic over time. Minor ulcers in the bladder or vagina that would normally heal may instead enlarge and eventually perforate, forming a fistula [14]. Microscopically, radiation causes endarteritis (inflammation and obliteration of arteries), chronic ischemia, and fibrosis (**Figure 3**). Clinically, this appears as nonhealing ulcers, strictures, and tissue breakdown. For example, years after cervical cancer radiotherapy, a patient can develop a VVF at the site of maximal radiation injury.

Radiation-induced fistulas typically present late, often years or decades after treatment, due to the slow progression of tissue damage [15]. Even minimal trauma (e.g., a biopsy or minor surgery) in a previously irradiated field can precipitate a fistula because the tissue integrity is so poor. These fistulas are often complex, surrounded by dense fibrosis and scar tissue, which makes surgical repair challenging. Common scenarios include vesicovaginal or RVFs after radiation for cervical cancer, and rectourethral fistulas after prostate cancer radiation [16, 17]. The underlying pathogenesis in all cases is chronic ischemic necrosis secondary to radiation damage [18].

Despite advances that make radiotherapy more targeted, radiation-induced fistulas remain a significant issue. Modern practice limits pelvic radiation to cancer treatment, but if radiotherapy is given before or soon after surgery, it greatly impairs tissue-healing capacity. Accordingly, radiation-related fistulas often require a prolonged waiting period before an attempt at repair (to allow some fibrosis to mature and inflammation to subside), and even then, the success rate of repair is lower than that for nonradiation cases due to the poor tissue quality.

3.4 Malignant causes

Advanced malignancies can directly create fistulas through invasive tumor growth or tissue destruction. A tumor located between two organs can erode

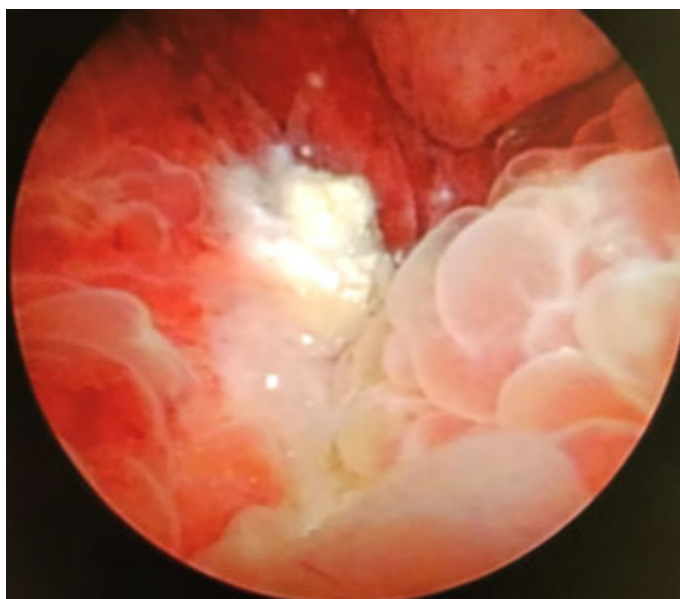


Figure 3.
Endoscopic features of radiation-induced tissue damage.

through tissue planes as it enlarges, forming a pathological connection. For instance, cervical cancer is the most common malignant cause of VVF because an invasive cervical tumor at the anterior cervix can ulcerate into the bladder base. Other gynecologic cancers (vaginal, uterine) in advanced stages may similarly invade the bladder, urethra, or rectum. In the urinary tract, an invasive bladder cancer can erode into the vagina or uterus, though this is less common [19].

The pathophysiological mechanism is predominantly tumor-driven tissue necrosis: As tumors enlarge, they outgrow their blood supply, ulcerate, or become infected, resulting in the breakdown of the intervening tissue [20]. Malignant fistulas usually indicate quite advanced disease and often occur in the context of other signs of cancer (e.g., vaginal bleeding, weight loss, visible tumor). The fistula's location generally reflects the tumor origin (e.g., bladder–vaginal fistula in cervical cancer, rectovaginal in vaginal cancer, rectovesical in rectal cancer, etc.) [20]. Because of the active cancer and poor tissue quality, definitive fistula repair is usually deferred until the underlying malignancy is treated or controlled. Even then, surgical repair is difficult, and recurrence is common if cancer or radiation damage persists.

3.5 Infectious and traumatic causes

Severe infections are a less common cause of urogenital fistulas but can be relevant in areas where chronic infections prevail. Genitourinary tuberculosis is the classic infectious etiology: TB infection in the bladder or female genital tract causes granulomatous inflammation and tissue necrosis, which can erode into adjacent organs, producing fistulas if untreated [21–23]. Tertiary syphilis may form gummas that ulcerate, while lymphogranuloma venereum and other chronic sexually transmitted infections can similarly cause destructive ulceration of the genital tract [13]. These infectious causes are rare today, where such infections are promptly treated.

Postoperative or posttraumatic infections can also contribute. A pelvic abscess or infected hematoma after surgery or obstetric trauma can burrow into nearby organs. For example, an abscess at a vaginal cuff or perineal wound can erode into the bladder or rectum, leading to a fistula if not drained. Poor vascularization and chronic inflammation impede healing and promote fistula tract formation in these cases.

Additionally, neglected foreign bodies in the vagina (such as a forgotten pessary) can cause chronic pressure and ulceration, eventually creating a fistula between the vagina and the bladder or rectum [13].

4. Types of urogenital fistulas

Urogenital fistulas are classified by the organs involved. The major types include fistulas between the urinary tract and the female genital tract, as well as fistulas between the urinary tract and the gastrointestinal tract. Below, we describe the most common types and their characteristics.

4.1 Urethrovaginal fistulas

An urethrovaginal fistula is an abnormal tract between the urethra and the vagina. These typically result from trauma to the urethra during obstetric or gynecologic procedures. For example, a fistula may occur after an anterior vaginal wall repair (anterior colporrhaphy) or during the excision of a urethral diverticulum or Skene's gland cyst. It can also occur due to complications of anti-incontinence procedures (e.g., urethral sling erosion) or inadvertent urethral injury during vaginal surgery. In recent years, additional causes have included urethral surgery for recurrent UTIs (e.g., surgery for postcoital cystitis) and suburethral sling procedures for stress incontinence. Urethral injury from sling placement can occur during the blind passage of trocars in a fibrotic or atrophic anterior vaginal wall [24, 25] (**Figures 4 and 5**).

In one series of 216 urogenital fistula cases over 35 years, about 8% were urethrovaginal fistulas. Gynecologic surgery was the cause in 40% of those, and obstetric trauma in 35% [26–27]. Risk factors that increase the likelihood of urethrovaginal fistula include prolonged second-stage labor (leading to compression of the urethra against the pubic bone, causing ischemic injury), an anatomically contracted pelvis or large fetal head, use of obstetric forceps, and destructive childbirth procedures in obstructed labor. Additional risk factors include atrophy of the anterior vaginal wall and urethral tissues in postmenopausal women, as well as tissue thinning or fibrosis after prior surgeries. Minimizing the risk of bladder and urethral injury requires strict adherence to surgical technique. Pelvic bone trauma accounts for 11% of urethrovaginal fistula cases, and sexual trauma accounts for 5% [28].

Clinical features: The presentation depends on the fistula's location along the urethra. If the fistula is very distal (near the external urinary meatus), the continence mechanism may remain intact – the woman will void normally, but during urination, some urine passes through the vaginal fistula (a complaint of “two streams” or vaginal voiding). If



Figure 4.
Urethrovaginal fistula.

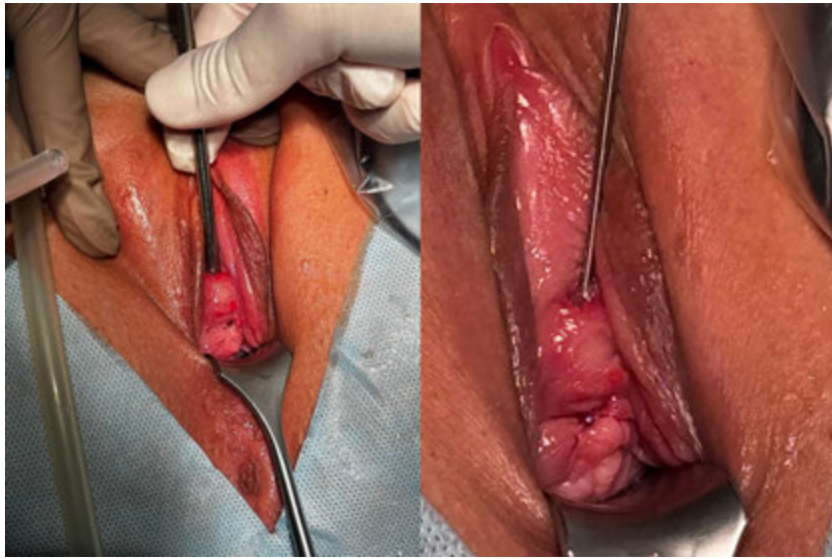


Figure 5.
Urethrovaginal fistulas.

the fistula involves the mid or proximal urethra (above the sphincter), there will be continuous leakage of urine, since the urine bypasses the sphincter and drains out through the vagina. On examination, a fistula connecting to the urethra may be seen just inside the vaginal introitus or along the anterior vaginal wall. In some cases of obstetric injury, an urethrovaginal fistula is accompanied by scarring or loss of part of the urethra.

4.2 Vesicovaginal fistulas

A vesicovaginal fistula is a communication between the bladder and the vagina (**Figure 6**). VVFs are generally categorized into two primary etiologic types:

- Iatrogenic VVF, resulting from surgical or obstetric procedures (e.g., hysterectomy, cesarean delivery).
- Ischemic (obstetric) VVF, caused by prolonged or obstructed labor, leading to pressure necrosis.

It is widely accepted that fistulas arising as surgical complications usually stem from direct injury to the lower urinary tract during pelvic procedures. Technical complexity, urgent/emergent conditions, or unrecognized injuries during surgery increase the risk. VVFs in developed countries are predominantly postoperative, with up to 75% occurring after hysterectomy procedures [13]. Acute or chronic postoperative urinary retention may also play a role in fistula formation. Altered pelvic anatomy (e.g., distortion by large ovarian tumors, adhesions binding the bladder to the uterus or cervix from prior surgery or endometriosis, or infection) is another contributing factor, as it makes surgical dissection more difficult. Surgical technique is critical: Careful identification and protection of the bladder



Figure 6.
Vesicovaginal fistula.

during pelvic surgery and prompt repair of any intraoperative injury help prevent VVF.

Obstetric (ischemic) VVFs are discussed above under obstetric fistulas. In short, they result from tissue necrosis due to obstructed labor. These tend to be large defects with substantial tissue loss. In contrast, postsurgical VVFs are often smaller and located at the vaginal vault or along suture lines (e.g., after hysterectomy).

Clinical features: VVF typically presents as continuous, involuntary leakage of urine via the vagina, bypassing the urethra. The patient often reports being constantly wet. If the fistula is large, the patient loses all ability to hold urine. In some cases of a very small fistula, especially if it is high in the vagina, the patient may still void normally in small amounts but have continuous dribbling as well. When a fistula is associated with extensive tissue damage (such as in obstetric or radiation cases), the diagnosis is usually obvious from the history and examination. However, very small fistulas (e.g., from a gynecologic surgical injury) might have more subtle symptoms and can be difficult to visualize on examination.

4.3 Vesicouterine fistulas

A vesicouterine fistula is a tract between the bladder and the uterus. VUFs are relatively rare, accounting for approximately 1–5% of all urogenital fistulas [28, 29]. The majority of VUFs are iatrogenic – often arising from unrecognized bladder injury during obstetric or gynecologic surgery, most commonly during a lower-segment cesarean section (**Figure 7**). The incidence of bladder injury during cesarean delivery is low (approximately 0.3% of cases) [30], but when it does occur



Figure 7.
Vesicouterine fistula.

(especially if not immediately repaired or if the repair breaks down), a fistula can form between the bladder and the uterus or cervix.

The most common timing of bladder injury in cesarean is during the separation of the bladder from the lower uterine segment (approximately 43% of bladder injuries), followed by injuries during abdominal entry (33%) or uterine incision and delivery of the baby (24%) [31]. Other less common causes of VUF include the following:

- Myomectomy and metroplasty, especially in cases involving cervical or inter-ligamentous fibroids where the uterine cavity is opened;
- Vaginal deliveries after a previous cesarean section, particularly in the presence of a weakened uterine scar;
- Operative vaginal deliveries, use of forceps, surgical abortions, or uterine perforation during intrauterine device insertion; and
- Infectious etiologies, such as genitourinary tuberculosis.

The growing rate of cesarean deliveries has led to a proportional rise in women with uterine scars, including dehiscent or “incompetent” scars. Surgical repair of uterine scars – especially when complicated by dense adhesions or bladder invasion, visualized on imaging – poses a risk of bladder trauma during metroplasty.

Clinical features: VUFs classically present with the triad of cyclical hematuria (menstrual blood entering the bladder, causing menstruation via the urethra), amenorrhea, and urinary incontinence – this is known as “Youssef’s syndrome.” However, not all patients exhibit the full triad. Some women with VUFs remain dry (continent of urine) because the fistula is high and one-way (allowing uterine contents to pass into the bladder but not urine into the uterus). These patients may report cyclic hematuria (blood at menses coming out with urine) and absence of vaginal menses. Others may experience intermittent urinary leakage, often

positional (e.g., leaking only when lying down), or report a continuous watery vaginal discharge if urine passes from the bladder to the uterus and out through the cervix intermittently. Because these fistulas occur after cesarean sections, patients are often younger and may desire future fertility, which influences management (surgical repair ideally without hysterectomy).

4.4 Ureterovaginal fistulas

These fistulas most commonly develop following radical surgery for malignant tumors of the cervix or uterine body, as well as hysterectomy performed for large uterine fibroids. Ureteral injury may also result from thermal damage during laparoscopic procedures [7].

The ureter is highly vulnerable during pelvic surgery due to its anatomical course through the retroperitoneum. An UVF typically arises from injuries that compromise the ureteral wall or cause delayed necrosis, leading to urine extravasation (**Figure 8**) [32]. Ureteral injuries can be acute or delayed:



Figure 8.
CT scan – Ureterovaginal fistula.

- Acute injuries are usually recognized intraoperatively and include trauma from suture ligation, direct incision or transection, or crushing.
- Delayed injuries often result from energy-based therapies such as heat ablation, cryoablation, or radiation, which cause ischemic changes and progressive tissue necrosis [33].

Understanding the anatomical pathway of the ureter is critical for recognizing potential injury sites. The ureter descends through the retroperitoneum, following the anterior psoas muscle, passing posterior to the colonic mesentery, and running lateral to the gonadal vein [34]. Approximately 80–90% of ureteral injuries occur in the distal ureter, where it crosses beneath the uterine vessels [35].

While UVFs can result from colorectal, vascular, or urological surgeries, gynecologic operations account for the majority of cases. More recent data (published in 2025) suggest an increase in ureteral injuries in minimally invasive hysterectomy (MIH) compared to open hysterectomy: 0.95% vs. 0.57%, respectively (MIH cohort showing higher risk, $p < 0.01$) [36]. According to the EAU Urological Trauma Guidelines (March 2023; reprinted in 2024 and 2025), iatrogenic ureteral injury rates vary by procedure: 0.01–0.06% in emergency cesarean delivery; 0.02–0.5% in vaginal hysterectomy; up to 2.0% in abdominal hysterectomy; 0.13–6.0% in laparoscopic hysterectomy; and 1.7–4.3% during urogynecologic operations (e.g., prolapse or anti-incontinence surgery) [37–40]. Notably, most injuries occur during routine, uncomplicated procedures with apparently normal pelvic anatomy. Unfortunately, many injuries go unnoticed during surgery and become symptomatic only postoperatively [41].

Risk factors for UVF formation include the following:

- Endometriosis
- Obesity
- Pelvic inflammatory disease
- Pelvic radiation therapy
- Pelvic malignancy

Clinical features: An UVF classically causes continuous urine leakage from the vagina while the patient still has normal voluntary bladder function. In other words, one kidney's output leaks out unimpeded, but the other kidney empties into the bladder normally, so the patient can still void some urine. Patients often describe two streams of urine or continuous dribbling in addition to normal urination. They may initially present with flank pain or fever from urine backup (if the ureter was obstructed before it fistulized); once the fistula opens, the pain often subsides as urine is no longer obstructed. Over time, if untreated, an UVF can lead to loss of function in the affected kidney due to continuous infection or obstruction. On examination, the bladder is intact (dye tests will show the bladder dye does not appear in the vagina, but urine from the kidney – often visualized by giving oral

phenazopyridine – is seen leaking). UVFs frequently occur after hysterectomy, so the vaginal cuff is a common site for the fistula opening.

4.5 Rectovaginal fistulas

A rectovaginal fistula is a tract between the rectum and the vagina. This is technically a type of enterogenital fistula (between the GI tract and genital tract). RVFs result in the passage of flatus or feces from the vagina. The most common causes are obstetric trauma and inflammatory bowel disease. Obstetric RVFs often occur from a third- or fourth-degree perineal tear during childbirth (a laceration extending through the anal sphincter into the rectum) that either goes unrecognized or breaks down due to infection. Inadequate repair of such obstetric perineal injuries can lead to a persistent RVF. Prolonged obstructed labor can also create pressure necrosis that causes both a VVF and an RVF (a “double fistula”) when the tissue between the rectum and the vagina and between the bladder and the vagina all becomes necrotic.

Apart from childbirth injuries, Crohn’s disease is a major cause of RVFs in developed countries. Crohn’s (a transmural inflammatory bowel disease) can cause deep ulceration of the rectovaginal septum and lead to fistula formation. Radiation therapy for cervical or rectal cancer can also cause RVFs as a late complication, similar to how radiation causes VVF (fragile, scarred vaginal and rectal tissues break down). Less commonly, surgical injury during procedures such as a difficult episiotomy, a low colorectal resection, or cancer surgery can create an inadvertent communication between the rectum and the vagina.

Clinical features: RVF patients often report the passage of gas or stool via the vagina and recurrent vaginal infections. Small, low RVFs (near the perineum) might only allow flatus and liquid stool to escape intermittently, whereas larger fistulas result in continuous soiling of the vagina. On gynecologic examination, a RVF can sometimes be seen in the posterior vaginal wall; a dye test with the instillation of rectal dye can help confirm it. Patients may also have associated sphincter muscle injury if obstetric trauma was the cause, leading to fecal incontinence.

4.6 Rectourinary fistulas in men

In men, urogenital fistulas may develop secondary to malignant pelvic tumors, radiotherapy, or inflammatory bowel disease. Vesicorectal and urethrorectal fistulas are abnormal connections between the urinary tract and the rectum in men. These lesions may arise following rectal or urethral surgery, prostatectomy, endoscopic treatment of benign prostatic hyperplasia (BPH), or as a consequence of gunshot wounds and other traumatic injuries. These rectourinary fistulas are uncommon but devastating, often leading to fecaluria (stool in urine), pneumaturia (air in urine), and recurrent UTIs [42]. The major etiologies and risk factors include pelvic malignancies, pelvic radiotherapy, inflammatory bowel disease, prostate surgery (and related treatments), and trauma. Each of these can contribute to fistula formation through distinct pathophysiological mechanisms, as detailed below.

Pelvic cancers can directly create fistulous connections by invading adjacent organs or indirectly via treatment complications. Colorectal (rectal) carcinoma is a classic example – a locally advanced rectal tumor may erode into the bladder or urethra, forming a rectovesical fistula. Although rare (under 1% of colonic cancers

cause enterovesical fistulas) [43], such malignant fistulas do occur, often heralded by new fecaluria or pneumaturia in a cancer patient. In prostate cancer, direct tumor invasion into the rectum is an uncommon cause of rectourethral fistula; instead, fistulas in prostate cancer patients usually result from therapy (surgery or radiation) [44].

Bladder carcinoma can occasionally invade posteriorly into the rectum as well (bladder cancer accounts for an estimated approximately 5% of vesicoenteric fistulas in some series) [45]. In all cases, the pathophysiology involves tumor-related tissue destruction: As the malignancy enlarges or ulcerates, it breaks down the normal separating fascia between organs, creating an abnormal tract. Furthermore, necrosis of tumor tissue can create an open channel. Clinically, any rectourinary fistula in a cancer patient warrants evaluation for tumor recurrence or progression at the fistula site [46].

Radiation therapy in the pelvis is a well-known risk factor for rectourinary fistulas. Men treated with radiotherapy (external beam or brachytherapy) for prostate or rectal cancer can develop fistulas months to years later as a late complication. Radiation causes progressive endarteritis and microvascular damage in normal tissues, leading to chronic ischemia, fibrosis, and poor healing capacity. Over time, irradiated tissues may ulcerate or break down, and an inflammatory or necrotic tract can form between the urinary tract and bowel. Notably, prior radiotherapy dose-dependently increases the risk of fistula formation after any surgical insult, and it decreases the likelihood of spontaneous healing. For example, men undergoing salvage prostatectomy after radiation have a much higher incidence of rectourethral fistula (rectal injury rates up to around 9% in salvage surgery vs. 0–4% in primary surgery). Overall, the reported fistula incidence after various pelvic radiation treatments ranges from 0.1% up to 3%, depending on modality and combination therapy [46].

Inflammatory bowel disease – in particular Crohn’s disease – is an important noniatrogenic cause of rectovesical fistulas. Crohn’s disease is characterized by chronic transmural inflammation of the intestinal wall that can penetrate into adjacent organs. Over time, deep ulcers and granulomatous inflammation can progress to sinus tracts and eventually fistulous connections. It is estimated that internal fistulas occur in up to one-third of Crohn’s patients [47], and among these, fistulas to the genitourinary tract (enterovesical fistulas) are a known complication (seen in roughly 2–10% of Crohn’s cases) [48]. In men, anatomically, there is no uterus separating the bowel from the bladder, so colovesical (bowel–bladder) fistulas are relatively more common in male Crohn’s patients [47]. The typical scenario is Crohn’s disease of the distal ileum or sigmoid/rectum that causes an abscess or phlegmon adhering to the bladder, eventually perforating into it.

Iatrogenic injury during prostate surgery is the single most common cause of rectourethral fistulas in men. In particular, radical prostatectomy (for prostate cancer) carries a small but significant risk – up to 1% of men undergoing prostatectomy develop a rectourethral fistula [49]. Most often, this stems from an unrecognized rectal perforation at the time of surgery. Early intraoperative repair of rectal injury reduces RVF risk from 75% to 15% [50]. The prostate lies just anterior to the rectum (separated by a thin fascial layer), so if the rectal wall is inadvertently entered or devitalized during dissection, a communication may form. Even a tiny intraoperative tear can enlarge postoperatively if not repaired, especially under the pressure of urine leakage or fecal contamination. The fistula

typically involves the area of the vesicourethral anastomosis (bladder neck to urethra connection) and the anterior rectal wall. Several factors increase the risk: Previous radiation (as noted above) makes tissues fragile and less likely to heal, and salvage prostatectomy (surgery after other treatments) has higher rectal injury rates [51]. Surgeon experience and oncologic factors (tumor adherent to rectum) also play a role. Besides radical prostatectomy, other prostate cancer therapies can lead to fistulas. Cryotherapy (cryoablation of the prostate) and high-intensity focused ultrasound (HIFU) are ablative treatments that destroy prostate tissue (often used for cancer) – if nearby rectal tissue is frozen or heated in the process, it can slough and create a tract. Indeed, rectourethral fistulas have been reported after cryotherapy, HIFU, and prostate brachytherapy (seed radiation). In one series, combining modalities (radiation plus surgery or ablative therapy) raised fistula rates up to 3% [52]. The unifying mechanism is iatrogenic injury: either a direct surgical incision into the rectum or thermal/radiation damage to the rectal wall. If the injury doesn't heal properly – for example, due to infection or compromised blood supply – a persistent communication between the urethra (or bladder) and rectum will form. This is why any prostatectomy patient with gas or stool per urethra must be evaluated for a fistula. Notably, while minor rectal injuries recognized at surgery can be repaired with low fistula risk, unrecognized or large injuries almost invariably result in fistula formation if managed conservatively [53].

Traumatic injury to the pelvis can cause vesicorectal or urethrorectal fistulas when both the urinary tract and bowel are simultaneously damaged. Penetrating traumas, such as gunshot wounds and shrapnel blasts, are well-documented causes. A high-velocity bullet can lacerate the anterior rectal wall and then exit through the bladder or prostate/urethra (or vice versa), creating an immediate communication. Even if surgically repaired, severe contamination and tissue loss may prevent full healing, and a fistula may develop along the injury tract [54]. In fact, in combat or civilian gunshot injuries to the bladder, concurrent bowel perforation is very common (over 80% of bladder gunshot wounds have an associated gastrointestinal injury) [55], underscoring how these connections form. Blunt trauma can also be implicated: For example, a crushing pelvic fracture from a road accident might rupture the urethra and tear the rectum, especially if bone fragments perforate the bowel. If not recognized and diverted, such injuries could heal with a fistulous connection. The pathophysiology in trauma is straightforward – direct tissue destruction and contamination. The normal separation between the urinary tract and rectum is violated by force, and if the resulting wounds do not close (often due to severe infection or inadequate blood supply in the damaged tissue), a chronic fistula tract epithelizes. In gunshot cases, foreign material (e.g., bullet fragments) can also persist and perpetuate inflammation, hindering closure. Thus, any penetrating pelvic trauma with persistent urinary leakage via the rectum is indicative of a fistula. Prompt diversion of the fecal stream and urinary drainage is crucial in acute management to allow healing, but often surgical reconstruction (e.g., using tissue flaps) is needed to definitively close trauma-induced fistulas [54].

Clinical features: Men with a rectovesical or rectourethral fistula usually present with the passage of urine via the rectum and/or the passage of stool or gas via the urethra. They often notice air bubbles in the urine (pneumaturia) or fecal particles in the urine (fecaluria) and frequently develop recurrent urinary tract infections. There may be

irritative urinary symptoms or prostatitis due to fecal contamination. Some experience local pain or signs of sepsis if the fistula is causing contamination of normally sterile areas. On examination, one may observe stool in the urine or, on cystoscopy/anoscopy, a visible fistula tract. In cases resulting from prostatectomy, the fistula usually connects the area of the vesicourethral anastomosis to the anterior rectum. In malignant or radiation-induced cases, the fistula may involve more lateral or superior aspects.

5. Classification

To date, there is no universally accepted classification of urogenital fistulas, largely due to the wide variety of anatomical locations and clinical presentations. Multiple classification systems have been proposed to categorize urogenital fistulas because of their variety in location and complexity.

5.1 Kan anatomy classification

This system is based on the location of the fistula and the organs involved in the pathological process (**Figure 9**). It distinguishes the following types:

- Vesicovaginal;
- Vesicouterine;
- Vesicoadnexal;
- Urethrovaginal;

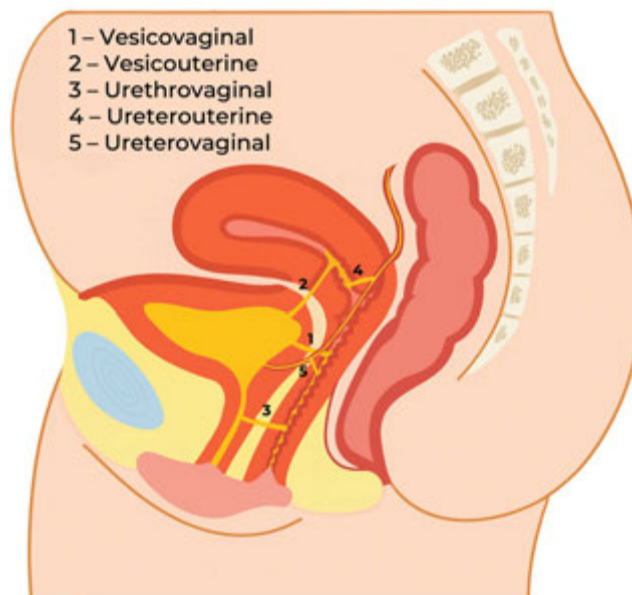


Figure 9.
Kan classification.

- Ureterovaginal;
- Ureterouterine;
- Combined (ureterovesicovaginal); and
- Complex fistulas involving both the genitourinary and gastrointestinal tracts.

5.2 Goh classification

The Goh system takes into account not only the anatomical site of the fistula but also its size, tissue condition, and ureteral involvement (**Table 1, Figure 10**) [56].

Distance from EUO to the distal edge of the fistula:	Fistula diameter	Tissue condition/additional features
1: ≥ 3.5 cm	a: < 1.5 cm	I: minimal fibrosis, vaginal length > 6 cm, good capacity II: moderate/severe fibrosis, suboptimal tissues
2: 2.5–3.5 cm	b: 1.5–3 cm	III: previous repair, radiation damage, circumferential defect, ureteral involvement
3: 1.5–2.5 cm	c: > 3 cm	
4: < 1.5 cm		

Table 1.
Goh classification.

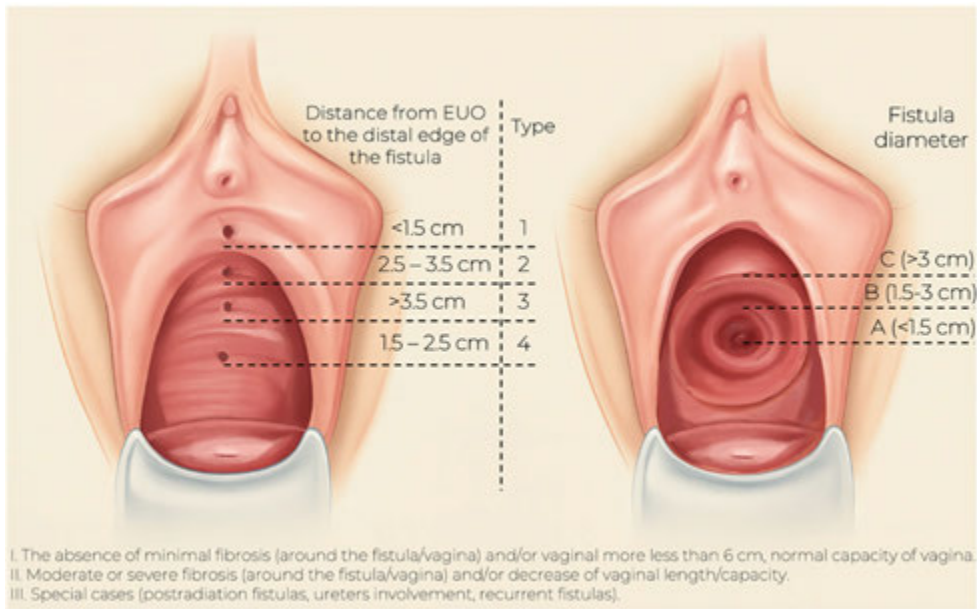


Figure 10.
*Goh classification. *EUO – external urethral orifice.*

5.3 Waaldijk classification

Type or size of fistula	Description
Type I	Fistula not involving the continence mechanism of the urethra
Type IIA	Fistula without (sub)total involvement of the urethra
Subcategory a	Without peripheral defect*
Subcategory b	With peripheral defect
Type IIB	Fistula with (sub)total involvement of the urethra
Subcategory a	Without peripheral defect*
Subcategory b	With peripheral defect
Type III	Miscellaneous, for example, ureteric and other complex fistulas
Small	< 2 cm
Medium	2–3 cm
Large	4–5 cm
Extensive	≥ 6 cm

*Complete separation of the urethra from the bladder.

Table 2.
Waaldijk classification of urogenital fistulas.

Summary **Table 2** of the Waaldijk classification of urogenital fistulas according to urethral involvement, fistula location, and defect size.

5.4 Classification of rectourethral fistulas

Criteria	Classification
Size ≥ 2 cm	Complex
Associated urethral strictures	Complex
Bladder neck contracture	Complex
History of external beam radiotherapy or focal therapies	Complex
None of the above	Simple

Table 3.
Classification of rectourethral fistulas.

Table 3 differentiating simple and complex rectourethral fistulas by size, stricture presence, bladder neck status, and radiation history.

5.5 WHO classification of urogenital fistulas

Criteria based on expected surgical complexity (**Table 4**).

6. Diagnosis

Evaluation of a patient with a suspected urogenital fistula has several goals: confirm the fistula's presence, determine its precise location and size, assess the condition of

Criterion	Favorable/simple prognosis	Complex/uncertain prognosis
Number of fistulas	1	Multiple
Location	Vesicovaginal	Rectovaginal, combined, involving the cervix
Size (diameter)	< 4 cm	> 4 cm
Involvement of urethra/continence mechanism	Absent	Present
Tissue scarring	Absent	Present
Peripheral defect*	Absent	Present
Degree of tissue destruction	Minimal	Severe
Ureter/bladder involvement	Ureters open into the bladder, not into the vagina	Ureters open into the vagina; bladder stones may be present
Number of prior repair attempts	No prior attempts	Previous unsuccessful repairs

**Complete separation of the urethra from the bladder.*

Table 4.
 WHO classification of urogenital fistulas.

surrounding tissues (and any associated organ damage), and identify any underlying cause (such as recurrent cancer in malignant cases). The findings will guide whether surgical repair is feasible and help in planning the optimal surgical approach.

6.1 Clinical examination

If a urogenital fistula is suspected, a careful pelvic examination is performed. Often, a speculum examination of the vagina can directly visualize a fistula opening (especially for a VVF or low RVF). The examiner should assess the size and location of any defect and the quality of the surrounding tissues (Are they supple or fibrotic? Is there evidence of radiation damage?). Sometimes, however, a standard examination in the clinic is limited due to patient discomfort or scarring.

Examination under anesthesia (EUA), which involves examining the patient under anesthesia (spinal or general), is extremely useful and is often performed just prior to surgical repair. Under anesthesia, muscles relax and pain is eliminated, allowing for a thorough and less hurried evaluation (**Figures 11 and 12**). The surgeon can gently probe the fistula tract, measure the distance from the urethra, and check vaginal capacity and scarring. It is important to assess vaginal elasticity and mobility of tissues – for example, is the upper vagina soft and mobile or fixed and scarred to the pubic bone? This influences the surgical approach and whether additional flaps might be needed. EUA also allows for interventions like ureteral stent placement: If a fistula is near the ureteral orifices or suspected to involve a ureter, the surgeon will often cystoscopically place stents in the ureters during the examination to protect them during the fistula repair. In complex cases, EUA is the time when decisions about the feasibility of repair versus the need for a staged approach (or urinary diversion) are made, in consultation with the patient and family.



Figure 11.
Examination under anesthesia: stone in the fistula.

6.2 Laboratory tests

Simple laboratory tests can assist in confirming the nature of fluid leakage. If there is doubt whether vaginal discharge is urine or something else (e.g., lochia or serous fluid), a fluid creatinine or urea test can be done. Placing a dipstick or sending the fluid for urea/creatinine analysis will show high levels if it is urine. For example, a patient with persistent wet vaginal packing after surgery could have the fluid tested – A high urea/creatinine content confirms a urinary fistula. This is a quick way to differentiate urinary leakage from merely an infected wound or normal postpartum discharge [118].

6.3 Dye tests

Dye testing is a cornerstone of fistula diagnosis. The basic principle is to color the urine from different sources and observe where the dye emerges. A common method is the three-swab test (or double-dye test). In this test, three tampons or swabs are placed: one in the upper vagina near the cervix, one at mid-vagina, and one at the introitus. Then, methylene blue or indigo carmine dye is injected into the bladder via a catheter, and simultaneously, the patient is given an oral dye (such as phenazopyridine, which colors urine orange) about 1–2 hours beforehand. After some time, the tampons are checked: If the upper tampons are blue, it indicates that the bladder dye has leaked through a fistula (i.e., a VVF) (**Figure 13**). If a tampon is wet with orange (but not blue), it means urine from the kidney (orange-stained by



Figure 12.
Examination under anesthesia: synthetic implant erosion.



Figure 13.
Vesicovaginal fistula: dye excretion during EUA.

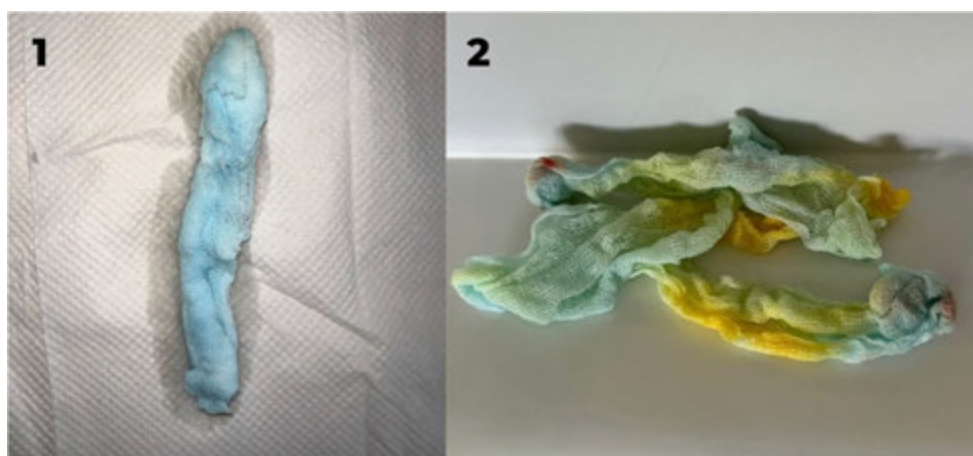


Figure 14.
Swab tests (1 – indigo carmine; 2 – indigo carmine dye + phenazopyridine).

phenazopyridine) is leaking – consistent with an UVF (because the bladder dye did not reach it) [57].

Often, a careful dye test can pinpoint multiple fistulas (e.g., one swab turns blue early, another later, etc., suggesting two tracts) (**Figure 14**). Intravenous indigo carmine can also be used to color the urine from the kidneys blue (instead of oral phenazopyridine) if needed. Another variation is instilling colored fluid in the vagina and looking for it in the catheter or vice versa (helpful for suspected urethrovaginal or complex cases). Additionally, giving a high-dose of vitamin B-complex can turn the urine bright green, which can sometimes be used as a third indicator.

6.4 Imaging studies

Imaging is adjunctive but can be very useful in complex cases.

- **Ultrasonography:** Pelvic or renal ultrasound has limited direct use in visualizing a fistula tract, but it is very useful for evaluating the upper urinary tract. For any fistula involving the ureters or associated with obstructive symptoms, a renal ultrasound should be done to check for hydronephrosis (dilation of the kidneys) [122]. For example, a long-standing UVF might show a loss of function in that kidney (shrunken kidney) or, if partial obstruction remains, hydronephrosis. Ultrasound can also detect any large postsurgical collections or abscesses that might relate to a fistula.
- **Computed tomography (CT):** Contrast-enhanced CT scans are increasingly employed to delineate complex fistulas. For instance, a combined vesicovaginal and UVF can be mapped by a CT urogram, showing contrast leakage from both the bladder and the ureter (**Figure 15**) [123]. CT is particularly helpful for enterovesical fistulas (e.g., colovesical fistula from diverticulitis) – oral or rectal contrast may extravasate into the bladder on CT. In female genital fistulas, CT is used when a comprehensive view of the entire pelvic anatomy is needed, or if the fistula tract is high and involves the ureter or kidney. Modern CT scans with

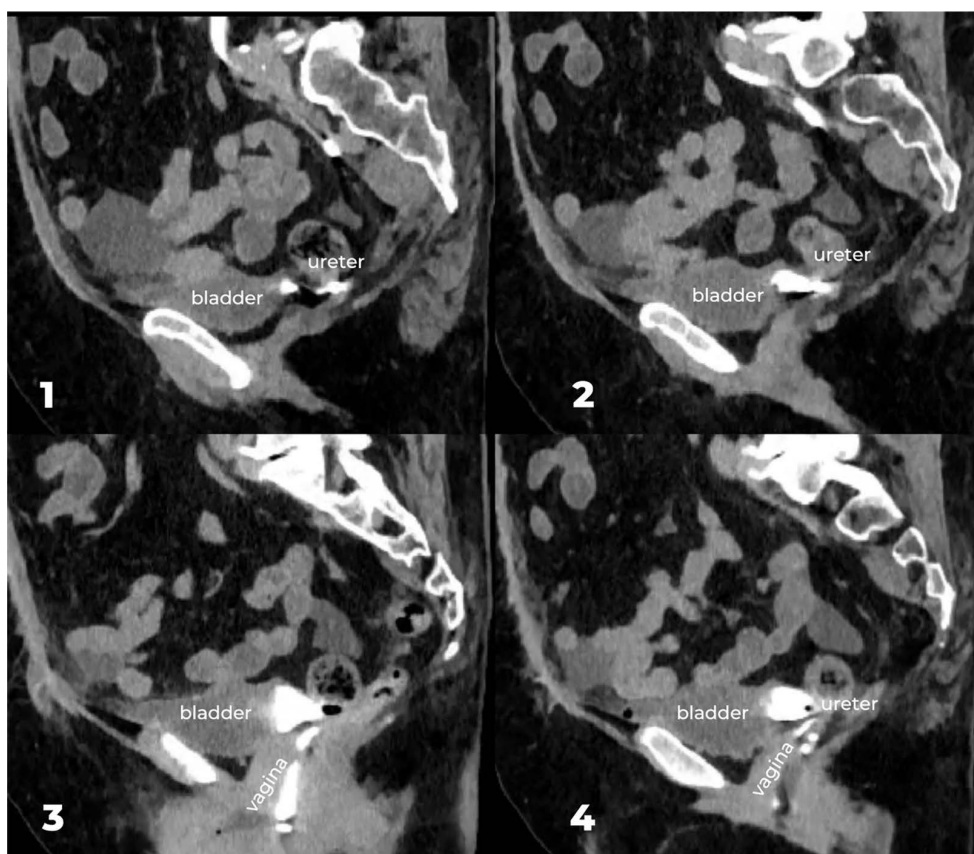


Figure 15.
CT scans of ureterovaginal fistula.

delayed phases can show leakage of contrast from the urinary system into the vagina or another organ.

- **Magnetic resonance imaging (MRI):** MRI is rarely a first-line option for fistula diagnosis, but it can be helpful in select cases. MRI provides excellent soft tissue contrast and can identify fistulous tracts involving soft tissue planes (e.g., a complex perineal fistula involving multiple organs, or when iodinated contrast cannot be used). In practice, MRI might be used for a patient who cannot undergo CT with contrast or when trying to distinguish fibrosis from an active tract in a radiated field.

6.5 Contrast studies

- **Cystography:** A voiding cystogram (filling the bladder with contrast and taking Xrays) can sometimes demonstrate a fistula by showing contrast leaking out of the bladder. However, small VVF may not be apparent on standard cystography – a dye test under direct vision is more sensitive. Cystography is more useful for VUFs (it may show contrast passing into the uterus or a uterine cavity outline on a bladder film). It is also used for suspected complex fistulas involving the

bowel; for example, cystography might show contrast in the colon if a colovesical fistula is present.

- **Fistulography:** This is a technique where contrast is injected directly into the fistula tract to delineate its course. For vaginal fistulas, a small catheter can be inserted into the fistula opening in the vagina, and contrast injected while taking Xrays. Fistulography is especially useful if the fistula leads to a cavity or sinus that is otherwise hard to evaluate (e.g., a fistula leading to an abscess pocket). It can show the full extent of a tract and any branching sinuses. In posthysterectomy vault fistulas or perineal fistulas, fistulography can help map them for surgical planning. One must be cautious, as it can sometimes introduce infection if not already present.
- **Vaginography:** In vaginography, the vagina is filled with contrast (often by inserting a Foley catheter into the introitus, inflating the balloon to seal it, and distending the vaginal canal with contrast) (**Figure 16**). If contrast is seen



Figure 16.
Vaginography used for the detection of vesicovaginal and vesicocolic fistulas.

flowing from the vagina into the bladder or urethra on Xray, it indicates a fistula. Vaginography can be valuable when multiple fistulas are suspected (e.g., combined ureterovaginal and VVF – contrast in the vagina might go into both the ureter and bladder through two tracts). This technique is less commonly performed today but remains an option for complex diagnostic problems.

- Excretory urography is a useful diagnostic tool for urogenital fistulas, particularly when ureteral involvement is suspected. Preoperative assessment of the upper urinary tract is essential. Ureteral dysfunction is a common finding in fistulas resulting from malignancy or its treatment (radiotherapy or surgery). Ureteral fistulas are always accompanied by ureteral dilatation. If dilatation of the ureter is found in a VVF, the possibility of a combined ureterovesicovaginal fistula should be considered.
- Retrograde pyelography is a more reliable method for determining the precise location of a ureteral fistula and can be combined with retrograde stenting or percutaneous ureteral catheterization.

6.6 Endoscopy

For fistulas that may involve the bowel or in cases of suspected malignant or radiation-related fistulas, endoscopic evaluation of the rectum/colon is important. Proctoscopy and colonoscopy allow direct visualization of the rectal mucosa and any fistula openings on the GI side. In a patient with a RVF who also has risk factors for Crohn's disease, a colonoscopy might reveal previously undiagnosed Crohn's inflammation or ulcers that caused the fistula. Biopsies of the fistula tract edges or any suspicious lesions can be taken during endoscopy to rule out cancer, which is particularly important in patients where the fistula could be due to recurrent malignancy or where the appearance is atypical.

In cases of radiation-induced fistulas, a rectoscopy is often performed to assess how severely the rectal tissue has been radiated, to check for any tumor recurrence, and to determine whether the rectal side of the fistula is small or large. Sometimes, multiple small radiation-induced rectal fistulas can be observed. This information helps determine whether surgical repair is feasible or if diversion is a safer option.

Cystoscopy (endoscopy of the bladder) is also a standard part of evaluation, especially for VVF and UVF. During cystoscopy, the fistula tract may be seen as a hole in the bladder wall (often near the vaginal cuff in VVF) (**Figure 17**). One can assess the trigone and ureteral orifices – if the fistula is very close to the ureteral orifice, that ureter may need reimplantation. Stones in the bladder (which can form secondary to chronic infection in fistula patients) can be identified and managed. If a ureter is draining into the vagina (UVF), the affected ureteral orifice may be difficult to find on cystoscopy or may be patulous. All this endoscopic information complements the external examination findings.

6.7 Nomograms

In recent years, significant efforts have been made to develop predictive tools for assessing surgical outcomes in patients with nonobstetric urogenital fistulas. One

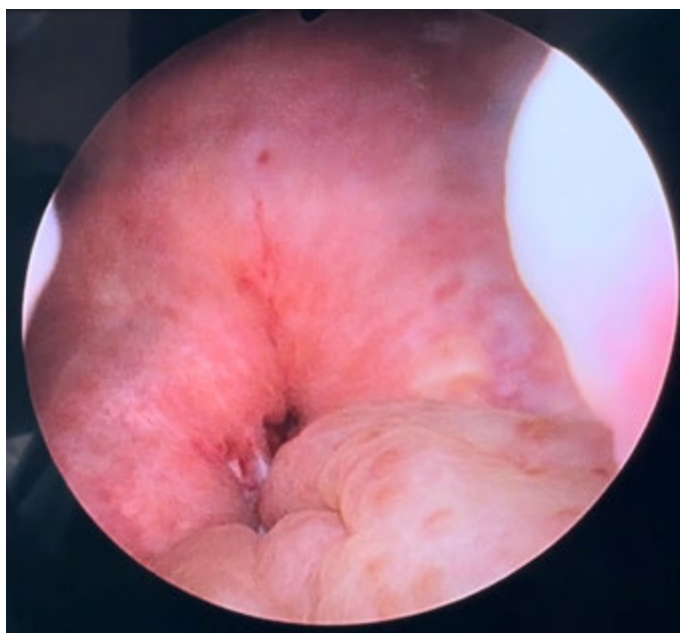


Figure 17.
Cystoscopy findings.

such approach involves the use of nomograms – graphical representations of multivariable statistical models that estimate the probability of a specific clinical outcome in individual cases.

A notable example of this methodology was published in 2022, presenting two nomograms based on a large retrospective cohort of patients with nonobstetric fistulas. The first model was designed to predict the risk of fistula recurrence following surgical repair, while the second estimated the likelihood of persistent lower urinary tract symptoms, defined as a UDI-6 score ≥ 6 , even after anatomically successful closure. These models incorporated key clinical variables such as fistula size, history of pelvic radiation, and prior vaginal surgery, identified through multivariate logistic regression [58].

7. Management

Management of urogenital fistulas can be divided into conservative (nonsurgical) and surgical approaches, with the vast majority eventually requiring surgery for a definitive cure. Preoperative optimization and postoperative care are also critical in achieving a successful outcome.

7.1 Conservative treatment

True spontaneous closure of an established fistula is extremely rare. Simply keeping the bladder drained with a Foley catheter will usually not heal a typical fistula, except possibly the very smallest and most recently formed ones. In a few cases, a tiny pinhole fistula or a very small UVF may close with prolonged catheter or

stent drainage, but this is the exception. As a general rule, continuous bladder or ureteral drainage that does not stop the leakage within a short period is not considered effective definitive treatment.

One scenario where conservative management might be tried is an immediate postoperative fistula detected very early; sometimes a week or two of catheterization is given to see if the fistula will seal on its own. Another is a small UVF – a ureteral stent may bypass the urine and allow the ureteric defect to heal. But beyond these unusual cases, conservative measures serve mainly as temporizing or preparatory measures rather than a cure.

Conservative management is, therefore, focused on preparing the patient for surgery and minimizing complications in the interim:

Bladder drainage – All patients with a fresh fistula should have a Foley catheter to minimize urinary soilage of tissues. This protects the kidneys and keeps the tissues as healthy as possible for eventual repair.

Incontinence supplies – Continuous leakage is socially isolating; patients are encouraged to use absorbent pads or devices to manage the leakage so they can participate in daily activities while awaiting repair.

Skin care – Urine irritates the vulvar and perineal skin, causing dermatitis. Topical barrier creams (zinc oxide paste, petroleum jelly, or silicone-based creams) are applied to protect the skin from maceration. If there is ammonia dermatitis, mild steroid ointments can be used for inflammation. Good hygiene, with gentle cleansing and keeping the area dry, also helps.

Infection control – If there is any urinary tract infection, appropriate antibiotics are administered to clear it before surgery. However, prophylactic long-term antibiotics are generally not recommended during the waiting period, as this can lead to the development of resistant bacteria. Some surgeons use a low-dose antiseptic (e.g., nitrofurantoin at night) in select cases, but this is not routine.

Estrogen cream – In postmenopausal women or cases of atrophic vaginal tissue, topical estrogen cream applied to the vaginal epithelium can improve tissue thickness and vascularity. This may aid healing and is often used in the weeks leading up to surgery for menopausal patients. (In young women with obstetric fistula who are amenorrheic from lactation or malnutrition, the benefit of estrogen is less established, but it is sometimes still tried empirically.)

Fluid intake – Patients sometimes reduce oral fluids in a misguided attempt to lessen leakage. This leads to concentrated, caustic urine, which actually further damages tissues and can cause stone formation on the fistula edges. Therefore, patients are encouraged to maintain a high fluid intake (at least 2–3 L per day) so that the urine stays dilute and less irritating. Good hydration also promotes higher urine output, which can help “flush” the system and reduce the risk of ascending infection.

Nutrition – Many obstetric fistula patients are malnourished. Optimizing nutrition (high-protein diet, treating anemia, etc.) in the preoperative period improves healing.

Timing of surgery – Perhaps the most important conservative aspect is choosing when to operate. Operating too early, before the fistula tract has demarcated or while tissues are inflamed, risks failure. Thus, an initial waiting period is often recommended. For obstetric fistulas, traditional teaching is to wait around three months after childbirth before repair. For radiation-induced fistulas, because of severe tissue damage, a waiting period of up to six to twelve months (with continuous diversion of urine or feces) is recommended to allow

radiation effects to stabilize [59–62]. Each case is individual – the key is to ensure no active infection or necrotic tissue at the time of repair. If a fistula is encountered intraoperatively (e.g., recognized during the causative surgery or immediately after), immediate repair at that time is indicated if the patient's condition allows. Early surgical closure (within 24 to 48 hours of injury) can be successful in fresh injuries. Otherwise, delayed repair after a few months is standard. Some studies suggest that if the fistula edges are clean and supple, one does not strictly need to wait three months for obstetric cases, but most surgeons still allow several weeks for edema or inflammation to subside. Overall, the absence of infection, necrosis, or inflammation around the fistula is the main criterion for proceeding with surgery.

7.2 Preoperative preparation

Proper preoperative preparation is a key to a successful fistula repair. This overlaps with some points above. Important elements include the following:

- **Infection control** – Ensure any urinary tract infection is treated, and the urine is sterile before surgery. If the fistula resulted from a pelvic abscess or wound infection, that infection must be resolved, and the patient should be on appropriate antibiotics if indicated.
- **Local tissue care** – Use estrogen cream for atrophic vaginal tissue (as discussed). In cases of edema or induration around the fistula, topical anti-inflammatory or antibiotic treatments can be administered if appropriate.
- **Counseling and consent** – Fistula surgery can be life-changing, but patients must understand the process. Surgeons should explain the plan, success rates, and the possible need for temporary or permanent measures. For example, if there is extensive damage, the patient is counseled that even after closure, she might have stress incontinence requiring further treatment. In radiation cases or multiple failures, the possibility of needing a urinary diversion (like an ileal conduit) should be discussed frankly.
- **Bowel preparation** – If the repair involves opening the bladder or working near the bowel (especially in rectovaginal or rectourinary fistulas), a bowel preparation is often performed. This can reduce the risk of infection by minimizing stool in the intestines around the surgical field. Typically, a mechanical bowel prep 1–2 days before surgery is administered for cases like VUF repair (to clear the colon) or for any fistula involving the rectum. In practice, many surgeons use a two-day mechanical bowel preparation for robotic UVF repairs.
- **Anesthesia and positioning planning** – Many fistula surgeries are performed with regional anesthesia (spinal) or general anesthesia. The team plans for patient positioning (usually lithotomy for vaginal approaches, low lithotomy with Trendelenburg for abdominal/robotic approaches, or prone jackknife for some transanal approaches). All necessary equipment (e.g., stirrups, padding) is prepared in advance.

- Adjuncts – Preop cystoscopy with ureteral stent placement is done immediately prior to surgery in cases where the fistula is near the ureter or to identify the ureters. This is part of the surgical plan (see below). If the patient has any urinary stones, those might be addressed cystoscopically before repair.
- Multidisciplinary support – Complex fistula cases may benefit from involving urologists, gynecologists, colorectal surgeons, etc. Preoperatively, the appropriate specialists are consulted if needed (e.g., in a rectourethral fistula, a colorectal surgeon may assist with the rectal repair, while an urologist handles the urinary repair).

7.3 Surgical management in women

Surgical repair is the definitive treatment for most urogenital fistulas in women. The approach depends on the fistula's location, size, and etiology. The two main surgical routes are transvaginal and transabdominal (which can be open, laparoscopic, or robotic). Whenever feasible, the vaginal approach is preferred for simple VVF because it is less invasive and has high success rates with low morbidity. However, fistulas that are very high (e.g., involving the ureter or high bladder), that are accompanied by severe scarring, or that require concomitant ureteral reimplantation often require an abdominal approach.

7.3.1 Fistula repair via vaginal approach

Most simple VVFs and many UVFs are repaired transvaginally. A helpful paradigm for fistula surgery is the “S–T–O–P” algorithm:

- S – seeing the fistula. Proper exposure of the fistula is critical. The patient is placed in the lithotomy position, usually under spinal or general anesthesia. EUA is performed to inspect the fistula. A weighted speculum, good lighting, and sometimes vaginal retractors or lateral sutures are used. Often, a Foley catheter is inserted through the fistula tract to serve as a guide (a Foley in the urethra drains the bladder, and a second small Foley or probe in the fistula helps identify its location). Any foreign bodies (sutures, mesh) are identified and removed. If there are stones in the bladder, they should be removed cystoscopically prior to repair. A biopsy may be taken of friable tissue if malignancy is a concern.
- T – timing. Ensure that the timing is optimal. As discussed, delayed repair if tissues are inflamed or recently irradiated. Intraoperatively, if tissues are found to be extremely friable (e.g., in a recent radiation fistula), one might abort and wait longer. Generally, by the time of planned surgery, this has been accounted for. If significant fibrosis is present, sharp dissection will be needed; sometimes very fibrotic, inelastic tissue may prompt an abdominal approach instead.
- O – operation planning. A thorough plan includes cystoscopy before the repair to locate the fistula and assess ureteral orifices. A 70-degree cystoscope is often used to visualize the bladder dome and anterior wall. If the fistula is near a ureter, that ureter should be stented to protect it. If the fistula is complex (e.g.,

vesicouterine or involving bowel), appropriate imaging (MRI or CT) would have been done to plan the approach. Necessary equipment (e.g., flaps, graft materials) is prepared. The patient has been bowel-prepped if needed, and antibiotics are given (usually a single preop dose, since it is a clean-contaminated case).

- P – proceeding. This refers to the key surgical steps of fistula repair (**Figure 18**):
 - a) Incision and exposure: A circumferential incision is made around the fistula opening in the vagina (often a few millimeters from the fistula edge in healthy tissue). If the fistula is close to the urethra, sometimes an inverted

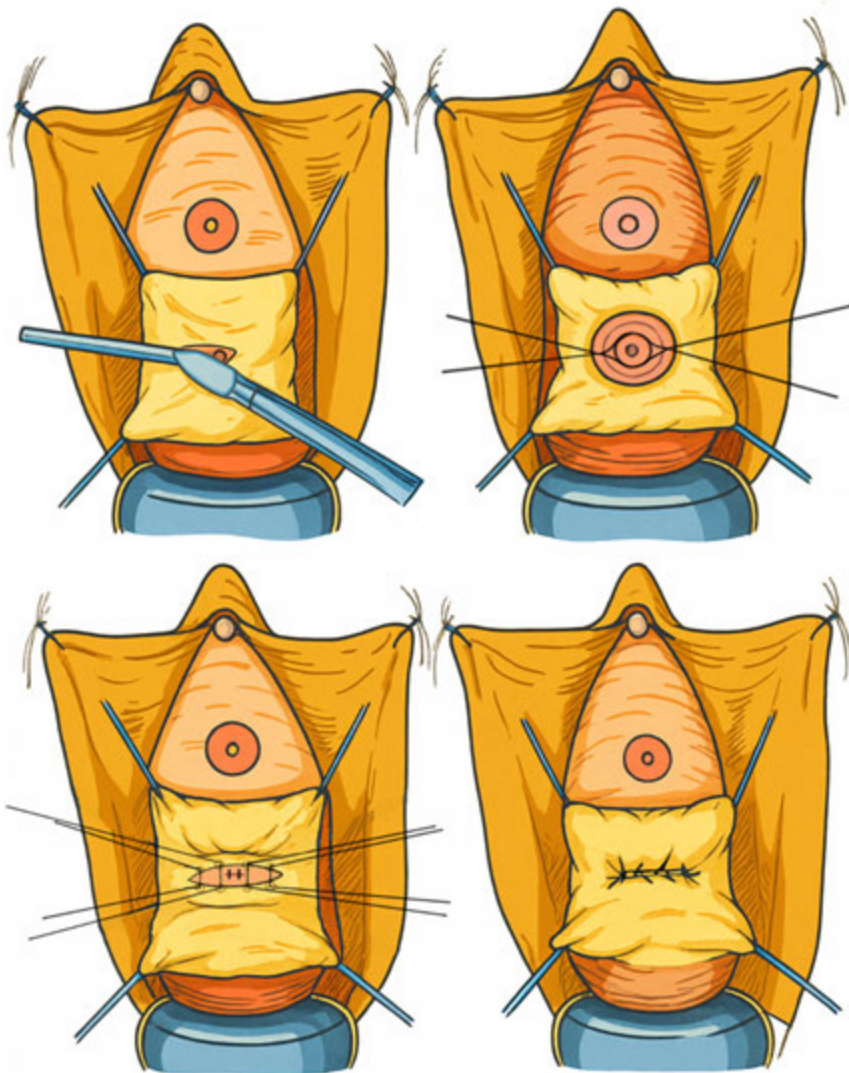


Figure 18.
Surgical steps of VVF repair.

“U” or extended incision is used to better mobilize the anterior vaginal wall. The scar tissue around the fistula is excised minimally (just enough to reach healthy tissue).

- b) Dissection: The vaginal wall is carefully dissected off the bladder (or urethra) to separate the two organs. This can be done by a splitting technique (simply separating the layers without excising the fistula tract itself) or an excisional technique (excising the fistula tract along with surrounding scar). The goal is to mobilize the bladder and vaginal wall fully apart, creating two healthy, well-vascularized surfaces for closure. Adequate mobilization is critical to ensure a tension-free repair.
- c) Layered closure: The bladder (or urethral) defect is closed in multiple layers, if possible. For a VVF, typically the bladder wall (detrusor/mucosa) is closed in two layers with absorbable sutures (e.g., 3–0 or 2–0 delayed absorbable) to make it watertight. The vaginal wall is closed separately over it. It is important that the suture lines of the bladder and vagina are offset (not directly on top of each other) to reduce fistula recurrence. In urethral fistulas, the urethra is similarly closed, and then a second layer of peri-urethral tissue is closed over it (see below for UVF specifics).
- d) Interposition flap (if needed): In difficult cases (recurrent fistula, radiation fistula, very large fistula), a tissue interposition may be added between layers. Commonly used flaps in vaginal repair are the bulbocavernosus fat pad (Martius flap), peritoneal flap, or gracilis muscle flap. These well-vascularized tissues are tunneled between the bladder and vaginal repair to provide an extra layer and blood supply. In first-time simple fistulas with healthy tissue, an interposition flap is often not necessary, but many surgeons will still place one if there is no downside (Martius flap has low morbidity) for extra assurance.

Throughout the repair, a Foley catheter is left in the bladder to keep it decompressed. The surgeon often fills the bladder with dilute methylene blue at the end to test for leaks (the “dye test” intraoperatively). If no leakage is seen, the vaginal wall is then closed over the repair. In uncomplicated VVF, typically a three-layer closure (bladder muscularis, bladder serosa or perivesical fascia, and vaginal wall) is performed.

During the vaginal repair, the patient is kept in lithotomy. If access is difficult due to scarring or vaginal stenosis, sometimes an episiotomy or releasing incision is performed to gain exposure. Good exposure is essential to properly mobilize and close tissues.

7.3.2 Latzko procedure

Latzko fistula repair was first described in 1942 for the treatment of small postradiation VVF in patients with severe trophic changes of the vaginal and bladder walls, which rendered standard fistula repair unfeasible [63]. The Latzko procedure can be classified as a high colpocleisis; it does not result in significant shortening of the vagina or impairment of sexual function.

7.3.3 Transvesical (suprapubic) approach

A transvesical approach is a type of abdominal repair where the fistula is repaired through the bladder without entering the peritoneal cavity. The bladder is opened extraperitoneally (for instance, via a Pfannenstiel incision), giving direct access to fistulas near the bladder base. This approach can be useful for fistulas near the bladder neck or urethra where a vaginal approach is not possible, and one wants to avoid a full transperitoneal surgery. The technique of closure is similar: The fistula tract is excised, and the bladder opening is closed in layers from within the bladder, while the vaginal side is closed from below or above as needed. The advantage is avoiding entering the peritoneum (potentially fewer adhesions, easier recovery), and it allows direct visualization of ureteral orifices for stent placement. However, a transvesical incision does create an additional incision in the bladder, which could slightly impact bladder capacity or function. It is typically used for select cases and is less common than standard transperitoneal or vaginal approaches.

7.3.4 Urethrovaginal fistula repair considerations

Repair of UVFs presents unique challenges because the urethra is a small tubular structure, and part of the continence mechanism may be compromised. UVFs are repaired exclusively via the vaginal route – approaching through the urethra or bladder is not feasible in most cases. One important point is that we generally avoid excising tissue in UVF repairs (unlike VVF, where the fistula edges are often freshened). In UVF, there is often a deficiency of urethral length, so trimming tissue would further shorten the urethra.

Key steps in UVF repair: (1) A circumferential incision is made in the vaginal wall around the fistula, and the vaginal wall is mobilized widely away from the urethral defect. The urethra and bladder neck are dissected free to allow tension-free closure. (2) The fistula edges in the urethra are not excised (to preserve as much urethral tissue as possible). Instead, the urethral defect is closed in a vertical fashion (sagittal plane) with fine absorbable sutures (3–0 or 4–0). This effectively closes the hole and slightly lengthens the urethra by bringing its edges together vertically rather than transversely. Any resulting narrowing is usually offset by the tissue mobility. (3) Because transverse closure can cause urethral stricture, it is avoided if it would constrict the lumen. The aim is to maintain a normal urethral caliber. (4) After the first layer repairs the urethra, a second layer of sutures is placed in the para-urethral fascia to reinforce and to separate the urethral repair from the vaginal wall. This layer helps buttress the repair and eliminate any dead space. (5) The vaginal wall is then closed over everything. Often, a Martius flap is interposed for UVF repairs, especially if the tissue was scarred or if the continence mechanism is questionable, to add bulk and blood supply.

By not excising edges and by mobilizing tissues well, one can close the urethral fistula without significantly shortening the urethra. If some urethral length is lost (say, a portion sloughed from obstetric injury), the remaining urethra can still function, though the patient often has stress incontinence afterward (because part of the sphincter mechanism was damaged).

Outcomes: Unfortunately, stress urinary incontinence is very common after obstetric or complex UVF repairs. Studies report that up to 50% of women with urethrovaginal fistulas will have residual incontinence, even if the fistula is

successfully closed [13, 32]. This is because the same injury that caused the fistula often destroyed parts of the continence mechanism (bladder neck, proximal urethra). These patients may later require an anti-incontinence procedure once healed (e.g., a sling). Typically, an autologous fascial sling is preferred in such fibrotic cases, since synthetic tapes might not hold well in scarred or irradiated tissue.

7.3.5 Martius flap

The Martius flap, or fibroadipose labial flap, was first described in 1928. The use of the Martius flap in the reconstruction of rectovaginal, vesicovaginal, and urethrovaginal fistulas significantly increases the success rate. The procedure begins with a lateral incision on the labium majus (**Figure 19**). The side of the flap harvest depends on the location of the fistula. Following a longitudinal incision on the labium

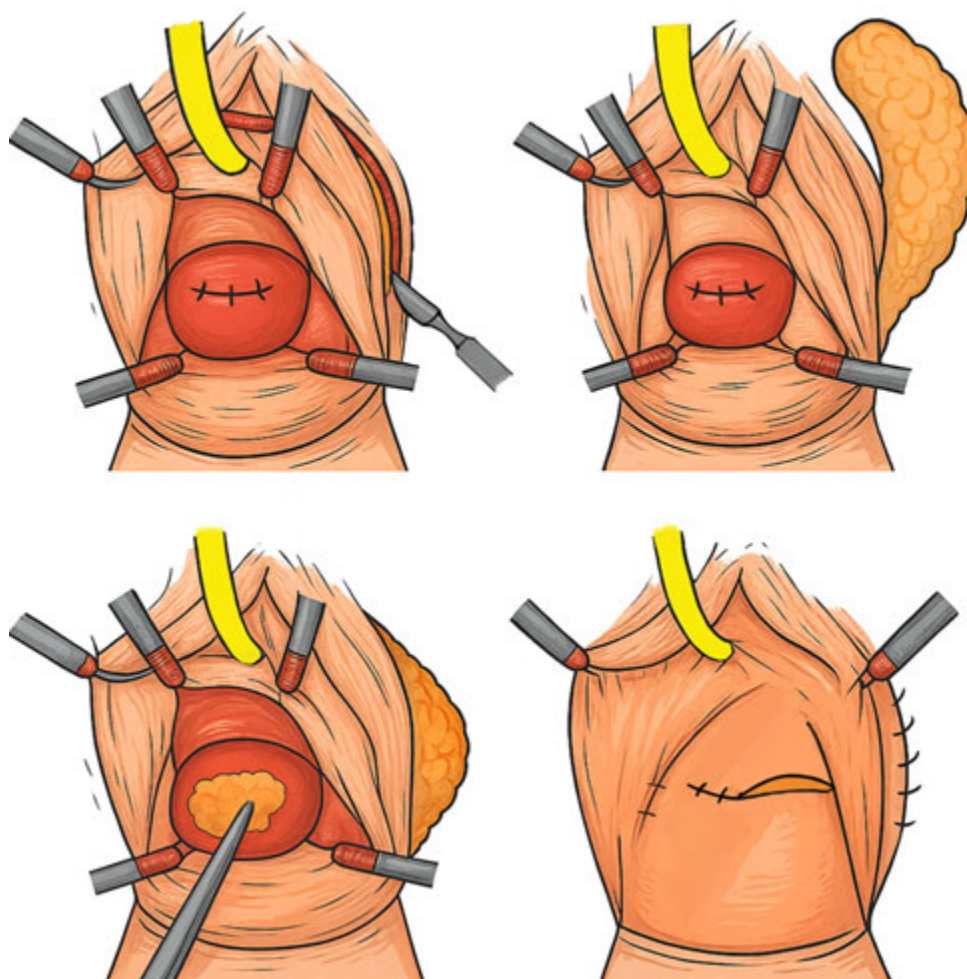


Figure 19.
The Martius flap.

majus, a vascularized labial fat flap is created and mobilized. A subcutaneous tunnel is then formed, through which the flap is transferred to the fistula site using a curved clamp. In most cases, the labial flap is easily advanced into the vaginal defect and provides excellent bulk for reconstruction. The labial incision is then closed, followed by the closure of the vaginal wall [64, 65].

7.3.6 Fistula repair via the abdominal approach

An abdominal (transperitoneal) approach to fistula repair is indicated when the fistula is high or cannot be safely reached vaginally, or when concomitant procedures are required. Examples include fistulas involving the ureter or high bladder (e.g., VUF), fistulas with significant bowel communication (requiring laparotomy), or cases where the vagina is obliterated by scar tissue so that a vaginal route is not feasible. Additionally, if a patient has multiple fistulas (e.g., a combined ureterovesicovaginal fistula), an abdominal approach allows for ureteral reimplantation simultaneously.

In an abdominal repair (open or laparoscopic), typically, the bladder is opened, and the fistula tract is excised from above. For example, in a VUF, one would open the bladder dome, excise the fistulous connection to the uterus, then close the uterus and bladder separately. Often, an omental flap is mobilized to place between the repaired organs. The omentum is an excellent interposition tissue; it can be brought down into the pelvis to lie between the bladder and vagina or bladder and uterus. In fact, during many open fistula repairs, the surgeon will routinely place an omental J-flap or sling to augment the repair.

7.3.7 Laparoscopic fistula repair

Laparoscopic fistula repair is effectively a minimally invasive abdominal repair. It was first reported in 1994, and since then, it has been performed by experienced centers. The principles (like the O'Connor technique for VVF; **Figure 20**) are the same: dissect the bladder from the vagina, close the fistula in layers, and use omentum if possible [66, 67]. Laparoscopy offers less morbidity than an open transabdominal approach, though it requires advanced skills in pelvic suturing. Robotic-assisted laparoscopy (discussed next) further facilitates this with enhanced dexterity.

7.3.8 Robot-assisted fistula repair

Robot-assisted laparoscopic repair has increasingly been reported for urogenital fistulas. The da Vinci® surgical system provides 3D magnification and articulating instruments, which improve upon standard laparoscopy in confined pelvic spaces. The first robotic VVF repair was performed in 2005 [68], and subsequent series have shown success rates near 100% for appropriately selected cases [69–73]. Robotic repair is often chosen for fistulas that are difficult to reach vaginally or that also require ureteral reimplantation (e.g., UVF). The advantages include reduced blood loss, precise dissection of scarred tissue, and fine suturing capabilities.

In a robotic VVF repair, the patient is placed in low lithotomy with steep Trendelenburg (head-down tilt) to allow the intestines to fall away from the pelvis. Ports are placed similar to those for a prostatectomy (typically 3–4 robotic arm ports

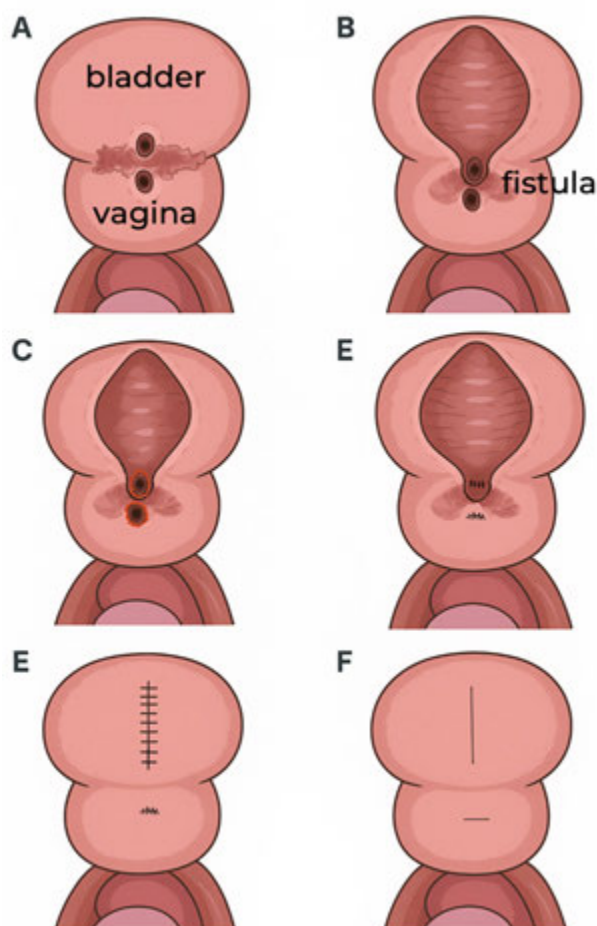


Figure 20.

O'Connor technique. A: complete dissection of the bladder (including development of the space of Retzius) and vagina. B: long sagittal cystostomy and bladder «hi-valving» until the fistula is clearly identified. C: complete transvesical excision of the fistula path. D, E, F: the layered closure of the bladder and vagina. Bladder, vagina, fistula – fistula path.

and one assistant port). The bladder is filled to identify the fistula if needed, and often a guidewire or Fogarty catheter is placed cystoscopically through the fistula to help locate it. The bladder is then opened (either directly over the fistula or via a separate incision, as in the O'Connor technique). Scar tissue is excised, and the bladder and vaginal edges are mobilized apart. The bladder defect is closed in two layers robotically (with 3-0 or 4-0 absorbable sutures), and the vaginal defect is closed (sometimes the vaginal incision can be left to heal if it is very high). An omental flap or peritoneal flap is often positioned between the closures. A leak test is performed by filling the bladder with saline and checking for no fluid in the pelvis. A Foley catheter and often a pelvic drain are placed.

Robotic repair follows the same principles of watertight, tension-free closure and often allows intracorporeal suturing that is as good as (or better than) open suturing due to the magnified view. Ureteral reimplantation can be performed during the

same robotic operation if needed. Randomized comparisons of repair with vs. without interposition tissue are lacking. Common options include peritoneal or omental flaps, pedicled rectus flaps, buccal flaps [74], or perisigmoid epiploic fat [71]. In cases where omentum is absent (e.g., after cancer surgery), rectus or epiploic flaps – or no flap – may be used [75].

Pneumoperitoneum leakage

Air leaks after opening the bladder/vagina can be minimized by placing wet gauze in the vagina or by using an AirSeal® valve-less trocar system [76].

Intraoperative identification

Cystoscopy remains the standard for identifying the fistula. A 5-F catheter or guidewire can be placed through the tract. Ureteral stents are recommended, especially for fistulas near the ureteric orifices. Some authors use combined cystoscopy and robotic camera visualization [77].

Postoperative care after robotic (or any abdominal) fistula repair includes leaving a Foley catheter in place for 10–14 days (some successful series remove it at 7 days for simple cases) [78]. Ureteral stents, if placed, are usually removed after approximately 4 weeks. The patient is advised to avoid strenuous activity and sexual intercourse for about 4–6 weeks to allow complete healing.

Special considerations: Surgeons have described two approaches in robotics – one is direct dissection of the fistula, and the other is a modified O’Conor approach with an incision away from the fistula to create more working space. The choice depends on the surgeon’s experience and the specifics of the fistula. Also, while vaginal repair is generally preferred for low fistulas due to less morbidity, if vaginal repair is deemed unsafe (e.g., due to severe fibrosis or difficult access), the abdominal/robotic route is chosen [61, 79–81]. Modern minimally invasive abdominal techniques are less traumatic than the classical ones [82, 83].

7.3.9 Robotic repair of UVF

A special scenario is an UVF requiring ureteral reimplantation. This can be done by open surgery but increasingly by robotic surgery.

Preoperative preparation for robotic UVF repair is intensive. As mentioned, a full mechanical bowel prep for two days is done (to allow plenty of working room and avoid bowel injury). All reconstructive options are discussed with the patient: In addition to the planned ureteroneocystostomy (ureter reimplantation into the bladder), possibilities such as using an ileal segment as a ureter substitute, a Boari bladder flap, psoas hitch, or even autotransplantation of the kidney or nephrectomy are reviewed. This is because if extensive damage is found (e.g., a long ureteric segment missing), alternative techniques may be needed. In essence, the patient is consented for a range of outcomes, from a straightforward reimplant to, in the worst case, removal of the kidney (though that is very rare). The patient is also counseled that while the plan is robotic (minimally invasive), conversion to open surgery may be necessary for safety.

In the operating room setup, the patient is under general anesthesia, placed in low lithotomy with steep Trendelenburg (for pelvic access). The robot is docked from the patient’s side or between the legs, depending on the system used. Proper padding is ensured due to the steep positioning (to prevent nerve injuries).

Port placement (trocar configuration) usually involves five ports: a camera port, two instrument ports for the robot, a third robotic arm port, and an assistant port.

The exact positions differ slightly for Si versus Xi robot models but essentially provide good bilateral access.

Instrumentation: Robotic instruments such as monopolar scissors, Maryland bipolar forceps, and needle drivers are used. Barbed sutures (e.g., 3–0 V-Loc) are often prepared for the ureter-to-bladder anastomosis to facilitate suturing without needing knots. A variety of other tools (clips, suction, etc.) are available to the assistant.

The surgical steps for a robotic UVF repair are basically those of a ureteric reimplantation with a psoas hitch and possibly a Boari flap, if needed:

1. **Adhesiolysis:** If the patient has had prior surgeries (often yes, since many UVFs occur after hysterectomy), there may be adhesions. The surgeon begins by carefully freeing the omentum and bowel from the pelvic area to expose the bladder and vaginal cuff. If the patient has a colostomy from a prior surgery, one works around it – a colostomy is not a contraindication but requires gentle handling. Adequate adhesiolysis ensures the bladder can be fully mobilized later and prevents inadvertent bowel injury during trocar placement or dissection. The ipsilateral colon may be mobilized upward to improve exposure of the ureter area.
2. **Exposure of the ureter:** The posterior peritoneum is incised along the line of the pelvic brim (over the external iliac vessels) to locate the ureter. The ureter is identified and then dissected downward toward the fistula site. Essentially, the surgeon frees the ureter from retroperitoneal attachments all the way to where it is damaged near the vaginal vault. Care is taken to preserve the ureter's blood supply (which runs longitudinally in its adventitia) while mobilizing it. The goal is to achieve enough length on the ureter to reimplant it into the bladder without tension. Usually, the ureter is freed down to the level of the bladder entrance (ureterovesical junction).
3. **Resection of damaged segment:** The ureter is transected above the fistula (at a healthy segment). The distal portion of the ureter (attached to the vagina or bladder) is often fibrotic and is removed or left closed. A Hem-o-Lok® clip or suture is placed on the bladder side to prevent urine spillage. The proximal ureter end is then spatulated (a cut made on one side to enlarge its opening). Spatulating the ureter (usually on the lateral side) creates a wider anastomosis.
4. **Bladder mobilization (and psoas hitch):** The bladder is then mobilized to allow it to move toward the ureter's new position. The space of Retzius (retropubic space) is opened by incising the peritoneum lateral to the medial umbilical ligament on the affected side. The bladder is freed from its attachments to the abdominal wall and cervix so it can be pulled upward. Often, a psoas hitch is performed: The bladder is sutured to the psoas muscle (at the level of the iliopsoas tendon) on the side of the injury, effectively elevating the bladder base toward the ureter. One or two absorbable sutures (e.g., 2–0) anchor the bladder wall to the psoas, avoiding the genitofemoral nerve on the muscle. This hitch shortens the distance for the ureter and also angles the reimplant to reduce tension. During this step, one must avoid injury to the genitofemoral

nerve on the psoas surface. The psoas hitch is a key maneuver if the ureter was cut relatively high.

5. Ureteroneocystostomy (reimplantation) ± Boari flap: A new opening is created in the bladder for the ureter, typically on the dome or anterolateral bladder on the side of the fistula. The bladder wall is incised approximately 1–2 cm. A double-J ureteral stent is inserted into the ureter and fed into the bladder to ensure patency. Then, the ureter is sutured to the bladder mucosa and muscle with a running absorbable suture (often double-armed for convenience). A tension-free mucosa-to-mucosa anastomosis is achieved. Next, a second layer of sutures secures the bladder muscularis over the ureter (to embed it and prevent reflux), and the peritoneum is closed over the repair. If the ureter is too short to reach, even with a hitch, a Boari flap is utilized: A flap of the bladder is raised and tubularized to bridge the gap. Essentially, a vertical flap from the bladder is created and pulled up to reach the ureter. The ureter is implanted into the apex of this flap. The flap is then rolled into a tube (bladder augmentation) to extend the bladder upward, which can add several centimeters of reach. The remaining bladder defect is closed in two layers. Boari flaps are more complex but allow very high ureteral injuries to be bridged without tension.
6. Closure: All counts are checked, and hemostasis is confirmed. The peritoneum is re-approximated over the bladder (reperitonealization) to isolate the repair from the abdominal cavity. A drain is left in the pelvis near the reimplant to monitor for any urine leak postoperatively. Trocar sites are closed, and the procedure is completed.

The patient is left with a Foley catheter (usually 10–14 days), and often the ureteral stent remains in place for around 4–6 weeks to ensure the new anastomosis stays patent during initial healing.

The outcomes of VVF repair have been widely reported, with success rates depending on the surgical approach, etiology, and surgeon expertise. A summary of selected recent studies addressing VVF repair is presented in **Table 5**.

7.4 Surgical management in men

Repairing rectovesical or rectourethral fistulas in men is challenging and often requires a multidisciplinary approach. Unlike most female fistulas, male fistulas frequently demand fecal and urinary diversion before definitive repair due to the high risk of sepsis. In general, once a rectourinary fistula is diagnosed in a man, a colostomy is usually created to divert stool, and a suprapubic or urethral catheter is placed to continuously drain urine. These measures allow infection and inflammation to resolve and optimize conditions for later surgical closure.

Conservative measures (like diversions) alone rarely result in closure; surgery is almost always needed in men. Because of the risk of severe urinary sepsis, active surgical management is the standard of care – one does not leave a man with a chronic rectoprostatic fistula without intervening.

Various surgical approaches exist: Historically, minimally invasive endoscopic attempts (e.g., clipping the fistula endoscopically, fibrin glue injection, or the use of

Surgical approach	Reported success rate	Key features	References
Transvaginal repair	86.7–90% (range 55.6–100%)	Less invasive, preferred for early and simple fistulas; good functional outcomes, cost-effective.	Hilton (2023) [84]; Li (2023) [85]
Transabdominal (open, O’Conor, modified)	83.3% (range 50–100%)	Used for high, complex, or recurrent fistulas; more invasive than the vaginal approach.	Hilton 2023 [84]
Laparoscopic repair	80–100%	Minimally invasive, reproducible O’Conor principles: an option after laparoscopic complications.	Miklos 2015 [86]
Robot-assisted repair	84.6% after primary surgery; up to 100% after redo procedures	3D vision, high precision, preferred in complex or ureteral cases.	Yang 2025 [87]; Stefanie 2020 [88]; Bodner-Adler B. 2017 [89]
Latzko partial colpocleisis	93–100%	High colpocleisis, useful for small postradiation fistulas, preserves vaginal function.	Kieserman-Shmokler 2019 [90]

Table 5.
Surgical outcomes of VVF repair.

an anal plug) have been described, but success rates are low. Open surgical repair typically necessitates extensive procedures, which may involve transabdominal, perineal, or posterior sagittal approaches. These methods are associated with significant risks, including postoperative erectile dysfunction and varying degrees of fecal or urinary incontinence [91–94]. In the last two decades, some have reported laparoscopic or robotic-assisted repairs for rectovesical fistulas in men [94–98]. These typically involve a transperitoneal approach to dissect and close the fistula with interposition of omentum. Hybrid techniques (combining transanal and transabdominal) have also been described. The approach is tailored to the fistula’s location and complexity. For example, a fistula after prostatectomy (located at the bladder neck/prostatic urethra to rectum) might be best approached transperineally or transsphincterically (York-Mason procedure), whereas a fistula after sigmoid resection might be higher and require transabdominal resection of the tract [99–102].

Patient preparation: Before definitive surgery, a thorough workup is done. This includes cystoscopy and proctoscopy/colonoscopy to delineate the fistula tract. Often, a catheter can be placed through the fistula to aid identification. The urinary tract is evaluated for stones or tumors (to ensure nothing else is complicating the picture). If the fistula is near a ureteral orifice, that ureter should be stented preoperatively to protect it. Broad-spectrum antibiotics (e.g., a fluoroquinolone or third-generation cephalosporin) are given preop, and the urine must be sterile (any UTI is treated). A bowel prep is also performed for most of these cases as part of improved rectal delineation and to reduce infection if entering the rectum. A rectal balloon can be inserted at surgery to help the surgeon identify the rectum.

The patient is typically diverted (colostomy) prior to reconstruction or at the time of reconstruction to ensure a clean field and a healing period.

Operative techniques:

One commonly used approach is the transperitoneal (transabdominal) approach, with the patient in a steep Trendelenburg lithotomy position, similar to the robotic prostatectomy setup. After entering the Retzius space (as in a prostatectomy), the bladder is mobilized down from the pubis, and the fistula area (bladder neck or prostate bed) is exposed. The fistula tract is then carefully excised, along with portions of the bladder neck/prostatic urethra and anterior rectal wall. The bladder or urethral opening is separated from the rectal opening.

Then, the rectal defect is closed in two layers: the inner mucosal layer with a running absorbable suture and the outer muscular layer with interrupted sutures. The bladder or urethral defect is also closed; if part of the bladder neck was opened, it is reconstructed with fine sutures. A well-vascularized tissue flap, usually omentum, is then interposed between the bladder and rectum to reduce recurrence. If omentum is not available, for instance, if it has been previously resected, a peritoneal graft or gracilis muscle flap from a perineal incision can be used.

Some surgeons perform this entirely robotically, which allows easy flap placement (the da Vinci Xi is particularly good at omental flap positioning due to its flexible camera placement).

Alternatively, a strictly perineal approach (often with the patient in lithotomy) can be used, especially if the fistula is low. The surgeon makes an inverted U incision in the perineum and splits the sphincter (if necessary) to gain access to the rectum and urethra. The tract is isolated and excised. The rectal wall is closed in two layers to prevent stricture. If the urethral defect is small (<2 cm), it is closed with fine sutures, and the urethra is mobilized to reduce tension. For larger urethral defects (2–6 cm of urethra missing), a buccal mucosa graft or a gracilis muscle flap neourethra can be used to reconstruct the urethra. The perineal approach gives excellent exposure and avoids an abdominal incision, but if the fistula is high (near the bladder), it might not reach.

The transanal (York-Mason) approach involves going through the anus and cutting through the rectal sphincter posteriorly to reach the fistula. This has fallen out of favor for postradiation cases because of poor healing. It involves splitting the sphincters, opening the posterior rectal wall, closing the fistula from inside, and then repairing the sphincters. Given the high incontinence risk and the complexity of many male fistulas (often radiated), this approach is now rarely used, except perhaps for very small mid-rectal fistulas in nonradiated patients.

Regardless of the approach, postoperative management mirrors that in women: bladder drainage via a Foley or suprapubic catheter for 2–3 weeks, fecal diversion (colostomy) remains until healing is confirmed, and avoiding stress on the repair (no straining, stool softeners, etc.). Many men will need further therapy, such as an artificial urinary sphincter or a bowel management program if incontinence results.

7.5 Single-port (SP) approaches in urogenital fistula repair

Single-port surgery has emerged as an advanced minimally invasive technique, aiming to minimize operative trauma while maintaining high surgical precision. Initially developed as laparoendoscopic single-site surgery, SP procedures have significantly evolved with the introduction of the da Vinci SP robotic system, which offers enhanced dexterity through a single multichannel port [103].

Advantages:

SP surgery reduces the number of incisions to one, improving cosmetic outcomes and potentially reducing postoperative pain and recovery time. The SP robotic system provides a flexible 3D camera and wristed instruments, which enable precise dissection and suturing in narrow pelvic spaces. Comparative studies in reconstructive urology show similar success and complication rates to multiport techniques, with possible benefits such as reduced blood loss and shorter hospitalization [103].

Challenges and limitations:

SP procedures have a learning curve, require specialized equipment, and are limited by a smaller selection of instruments compared to multiport systems. Complex fistulas requiring extensive tissue interposition or concomitant procedures may not always be suited for SP techniques. Patient selection and surgical expertise remain critical.

Applications:

VVF: Successful SP repairs have been reported via transperitoneal, transvesical, and even natural orifice (transvaginal NOTES) routes, achieving closure rates comparable to open or multiport repairs.

UVF: SP robotic ureteral reimplantation (including extraperitoneal approaches) has shown excellent results, with reduced pain and faster recovery.

Rectovesical and rectourethral fistulas: Early cases indicate the feasibility of SP transvesical or transanal approaches, though experience is still limited.

Urethrovaginal fistula: No large series yet, but the principles of SP repair are transferable, particularly for high bladder-neck fistulas.

Outcomes:

Initial studies report fistula closure rates of 90–100% with SP repairs, low perioperative morbidity, and rapid recovery. Long-term data are still limited, but early durability is promising [104].

8. Postoperative management

Postoperative care is crucial to the success of fistula surgery. The objectives are to keep the repaired tissues free of tension, allow time for healing, and prevent infection or stress on the repair.

- **Bladder drainage:** In almost all cases, a Foley catheter is left in the bladder after fistula repair. This continuously drains urine and keeps the bladder decompressed, which is essential for the healing of bladder and urethral sutures. The duration of catheterization varies with the situation: typically, about 10–14 days for a fresh, simple fistula repair (or an iatrogenic fistula repaired immediately). For obstetric fistulas (which often have more extensive tissue damage), many surgeons leave the catheter for 3 weeks. For radiation-related fistulas or very complex repairs, the bladder catheter may be kept for 3–4 weeks. Before removing the catheter, some centers perform a dye test (fill the bladder with methylene blue and check if any leaks into the vagina) – if a leak is seen, the catheter time is extended. If no leak is observed, the catheter is removed at the planned time, and a voiding trial is conducted.

- **Urinary antibiotics:** Prophylactic antibiotics during the catheter period are controversial. Many do not prescribe prolonged antibiotics due to the risk of resistance and infection with the catheter in place. Some may administer a low-dose nightly antibiotic (such as nitrofurantoin or trimethoprim), especially if the patient has undergone contaminated surgery, but generally, if the urine is sterile and catheter care is adequate, antibiotics are not continued. The patient is encouraged to drink plenty of fluids to flush the catheter and keep the urine dilute.
- **Bowel care:** If the repair involved the rectum or anal sphincter (in male or female RVFs), bowel movements may be diverted (colostomy), or if not, the patient is kept on stool softeners and a low-residue diet to minimize strain. If a colostomy was created, it is usually kept for 2–3 months until the fistula repair is well-healed, then reversed in a separate surgery.
- **Activity restriction:** Patients are advised to avoid heavy lifting, straining, or any activity that increases abdominal pressure for at least 4–6 weeks. They should not resume sexual intercourse for at least 4–6 weeks (and only after confirmation of healing). In VVF cases, intercourse too early could disrupt the repair. In obstetric fistula hospitals, patients often stay as inpatients for the full two weeks with a catheter, doing pelvic floor exercises and being monitored.
- **Follow-up:** Following catheter removal, patients should be carefully monitored to confirm the return of adequate voiding function. Extended periods of catheterization can lead to transient detrusor underactivity, necessitating a short period of bladder retraining or observation until normal micturition resumes. A final dye test or examination may be done to confirm closure. Any persistent incontinence is evaluated – for example, if the fistula is closed but the patient leaks on effort, she may have stress incontinence that can be addressed later.
- **Medical therapy:** A short course of an anticholinergic (e.g., oxybutynin) is sometimes given while the catheter is in place to prevent bladder spasms, which could stress the suture line. This is particularly common in repairs involving the bladder neck or urethra, where spasms might push urine past the catheter. If the patient has any signs of bladder irritation, these medications can help keep the bladder relaxed. Prophylactic antibiotics are reserved for specific indications (e.g., if the patient had positive urine cultures or needed them for another reason).

9. Prevention of urogenital fistulas

The development of urogenital fistulas is, in many cases, preventable, as it often results from identifiable clinical or surgical errors. Preventive measures should be adapted to the underlying cause and clinical context. In obstetric practice, timely relief of obstructed labor remains the most important step. Ensuring timely access to emergency cesarean delivery, strengthening intrapartum monitoring, and delaying early childbearing are widely recognized as effective preventive strategies.

International health organizations emphasize that strengthening maternal care systems and providing skilled birth attendance are crucial for eliminating obstetric fistulas. In gynecological and urological surgery, prevention relies on meticulous dissection and clear identification of pelvic structures. The routine application of intraoperative cystoscopy in technically demanding procedures is strongly recommended, as it enables immediate recognition and repair of inadvertent injuries to the bladder or ureters, reducing the risk of secondary fistula formation. When defects of the bladder or vagina must be repaired, a multilayer, watertight, tension-free closure remains the accepted standard. In patients at higher risk, the use of well-vascularized tissue interposition (e.g., omental or muscle flaps) may enhance healing and reduce recurrence.

In male urology, particular caution is required after endoscopic interventions for BPH, such as TURP or laser enucleation. Proper adherence to anatomical planes and avoidance of deep resection are important to minimize the chance of rectourethral fistula, a rare but serious complication. This risk increases in patients with prior pelvic irradiation; therefore, such cases demand special surgical judgment. Advances in radiotherapy, including image-guided and intensity-modulated techniques, have also contributed to reducing the incidence of radiation-related fistulas.

Overall, prevention of fistulas rests on a combination of public health measures, precise surgical techniques, and modern technological approaches. Integrating these elements is essential for lowering the incidence of fistula formation and ensuring better postoperative outcomes.

10. Conclusion

Despite a decline in incidence within high-resource healthcare systems – largely due to safer obstetric practices and refined surgical techniques – urogenital fistulas continue to cause significant patient morbidity. Recent advances in minimally invasive surgery, including robotic and SP approaches, have improved surgical precision and recovery outcomes. Future efforts should acknowledge that fistula prevention remains inherently challenging, particularly in complex pelvic surgeries, where anatomical distortion, prior interventions, or tissue compromise limits the ability to fully eliminate risk – even with advanced technologies and meticulous technique. Ultimately, meaningful progress in addressing urogenital fistulas will require a balanced approach – combining technological advances, refined surgical techniques, and preventive awareness – to improve outcomes and support patients' overall well-being.

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Section 2

Diagnostic Tools
in Functional Urology

Chapter 3

The Role of Videourodynamics in the Assessment of Bladder Dysfunction

Giovanni Palleschi, Valeria Rossi, Antonio Cardi and Fatma Abidi

Abstract

Diagnosis and management of lower urinary tract symptoms can sometimes represent a challenge. In complex cases, first-line diagnostic approaches and conservative treatment often fail, and the clinical condition may require advanced investigational methods. Videourodynamics is the most complete diagnostic evaluation of the lower urinary tract. Due to its minimally invasive characteristics, such as the need for bladder and rectal catheterization, the use of X-rays, and costs that are higher than non-invasive procedures (such as ultrasound), the international guidelines recommend the use of Videourodynamic in the following selected cases: when a conclusive diagnosis has not been achieved through first-line methods, in patients suffering from bladder dysfunction of neurogenic origin, and in those cases that require advanced diagnostic procedures for decision-making, especially before surgery. Experience with Videourodynamic is not widely represented in all urological centers and usually, this procedure is performed by dedicated, well-trained, expert urologists. For this reason, specific data on this topic are poorly represented in the scientific literature. In this chapter historical, technical, and clinical aspects of videourodynamics are described, reporting the application of this tool in different urological conditions: bladder outlet obstruction, neurologic disease, urinary incontinence, congenital disorders, inflammatory disease, and renal transplantation. For each of these topics, clinical indications, methods, outcomes, and utility of Videourodynamic are clearly described, showing the advantages that it can provide for proper diagnosis, contributing to making the best therapeutic choice.

Keywords: videourodynamic, urologic functional assessment, lower urinary tract dysfunction, bladder evaluation, imaging of lower urinary tract

1. Introduction

Bladder problems may arise from various pathological conditions that can have inflammatory, functional, neurological, neoplastic, congenital, and iatrogenic origins [1]. Diagnostic assessment of bladder dysfunction is generally based on history,

physical examination, laboratory findings, and ultrasound, which is easy to perform, requires a short execution time, and is also cost-effective [2]. Although some functional aspects of the bladder can be indirectly gathered from ultrasound studies (e.g., bladder wall thickness as a consequence of outlet obstruction), the most appropriate tool for the evaluation of bladder and lower urinary tract dysfunction (LUTD) is represented by urodynamics (UDM), which includes uroflowmetry, cystometry, and pressure-flow study, allowing a complete assessment of both bladder filling and emptying [3]. In addition, UDM can be performed with simultaneous electromyography of the pelvic floor muscles or external urethral sphincter, which provides very important functional information, especially in subjects suffering from neurogenic disorders. When UDM is combined with synchronous cystourethrography, which requires the use of contrast medium instead of saline solution and a radiological apparatus, a “videourodynamic” (VUDM) study is performed [4]. Videourodynamics allows for the simultaneous achievement of morphological and functional findings of the bladder and lower urinary tract; like traditional UDM, it can be associated with pelvic floor (through surface electrodes) or striated urethral sphincter electromyography (through a concentric needle). For this reason, VUDM offers a complete diagnostic evaluation of the lower urinary tract. International guidelines recommend the use of VUDM in selected cases [5]: First, when non-invasive diagnostic procedures do not provide a conclusive diagnosis; second, for the assessment of bladder dysfunction of neurogenic origin; and finally, in all cases that require advanced diagnostic procedures for decision-making, according to the clinician’s judgment. In this chapter, we discuss the technical aspects, methods, clinical indications, and outcomes of VUDM in the different fields of bladder and LUTD.

2. Historical data

After the development of UDM in 1954, the first VUDM was performed by Richard Turner Warwick in 1979 [3, 6], and was described by this author as the diagnostic method that “combines urodynamic traces with imaging of urinary tract using fluoroscopy or ultrasonography” [6]. The first machines utilized to perform the VUDM had a dedicated camera capturing the UDM analog traces through a fluoroscope, and for this reason, the prefix “video” was adopted. In these instruments, data were stored on a videocassette for subsequent analysis of the morphology and their interpretation. Since the late nineties of the previous century, the availability of digital support to record the radiologic images allowed the introduction of computer-based VUDM devices that strongly enhanced the diagnostic potential of this tool. In the following years, some additional advances in technology contributed to further improving the execution of digital VUDM: (1) the use of automated systems (provided with robotic arms) that help position the patient correctly by simply acting on electrical buttons; (2) the use of X-ray chairs that do not interfere with radiologic images during the test; (3) the use of modern fluoroscopic systems that have significantly reduced radiation exposure to patients due to the use of pulsed methods and improved detectors [7]. Furthermore, a series of software innovations that have been more recently added to the UDM systems and the radiologic instruments facilitate a better analysis of the results during the post-processing step, providing a significant contribution to better interpretation of the

results. Among these innovations are the software for superimposing different images for comparative analyses and the elaboration of specific nomograms for advanced interpretation of functional results.

3. Technical aspects

Instruments. The principles, methods, and technical requirements driving the execution of a VUDM must respect the instructions reported in the Good Urodynamic Practices, which are the standard guidelines for performing uroflowmetry, cystometry, and pressure flow studies. These guidelines are periodically updated and published by a dedicated working group of the International Continence Society [8, 9]. Specific indications regarding the simultaneous recording of digital images of the lower urinary tract are also reported in various additional documents and publications that provide suggestions to optimize the quality of the test and maximize its utility [10]. A detailed and dedicated report describing “Best Practice for Videourodynamics” has been published on behalf of the International Continence Society Urodynamics Committee by Mittal Patel et al. in 2024 [11]. All these documents precisely report indications, methodology, and technical aspects for performing UDM and VUDM, with procedural standardization. In the field of UDM, the standardization concerns not only specific technical issues but also clinical aspects, including patient assessment procedures and terminology that must be adopted to describe the outcomes [12]. Videourodynamic studies are performed using a UDM apparatus and X-ray equipment. The UDM apparatus is a multi-channel instrument capable of recording rectal pressure (through a rectal catheter), bladder pressure (through a bladder catheter), and the activity of the external urethral sphincter or pelvic floor muscles, which must be available for selected cases. Electromyographic systems associated with a UDM apparatus are usually characterized by an oscilloscope, whose signal is received by an audio device. The UDM system also includes a uroflowmeter that can be a “load cell type” (because it reports the speed of urine from the bladder by measuring the weight of the voided volume) or a “spinning-disk type” (because it measures the speed of the urine from the bladder using a rotating disk). The uroflowmeter is utilized either to assess the free flow of urine from the patient or to perform the pressure/flow study during bladder emptying in UDM and VUDM. The radiologic system for the VUDM is equipped with a digital fluoroscope to capture images, characterized by low-dose exposure and pulsed settings (**Figure 1**). Referral parameters based on previous studies that have standardized the procedure with a specific protocol are represented by 273.5 mGy/cm^2 , obtaining a mean of 5.1 pictures in 4.5 seconds [13]. Personnel who perform VUDM should be properly trained to limit radiation exposure. To obtain images of the lower urinary tract from multiple projections (antero-posterior, both sides lateral, and oblique), the radiologic apparatus must move from 90° to 180° , under the control of the operator from a remote location through a cloche or a mouse device. The X-ray system must be in a room with shielded doors and walls. It includes specific software and devices that allow: (1) superimposing the radiologic images on to the UDM traces and data; (2) storing the snapshots and UDM outcomes on digital supports. A very important aspect concerning the use of UDM and VUDM for the investigation of the lower urinary tract is the calibration of the system [14]. For this reason, operators



Figure 1.
Radiologic apparatus for VUDM, provided with a digital fluoroscopy.

performing VUDM must have a thorough knowledge of the system to ensure accurate calibration, which can prevent errors in the measurements of the different parameters and resolve minor technical problems that may develop during the examination [8]. The majority of studies report that monthly calibration is usually not associated with significant measurement errors [15]. Specifically, pressure transducers, flowmeters, and pumps need calibration before examining patients, following the manufacturer's guide.

3.1 Materials

Standardization of the VUDM procedure includes the use of specific usable devices.

Bladder catheters. The bladder catheters that are used for UDM and VUDM are characterized by a double lumen; one lumen is connected to the pump of the instrument, allowing bladder filling with saline solution (UDM) or contrast medium (VUDM); the other lumen relates to the extension line that carries the bladder pressure to a transducer. The size of the catheter utilized is 6 Fr, as recommended by the Good Urodynamic Practice, because nomograms and instruments are calibrated for tests performed with it [8]. Furthermore, this thin size can also be used in pediatric patients.

Rectal catheters. Abdominal pressures are calculated using a rectal balloon catheter connected to the extension line that comes from the abdominal pressure transducer. In the past, many clinicians used self-made rectal catheters using a 9 French Nelaton catheter. Nowadays, usable sterile rectal balloon catheters are available, which can be filled with saline solution before starting the exam.

Extension lines. Bladder and rectal catheters are connected to the UDM apparatus via thin tubes filled with saline solution, called *extension lines*; these tubes extend the length of the catheters to reach the pressure transducers. It is important that the extension lines do not contain air inside the lumen, as this can disturb the transmission of the pressure recorded by the catheters.

Transducers. The transducers of a UDM apparatus are connected to the extension lines and to the computer unit of the instrument. Their function is to convert the pressure incoming from the bladder and rectal catheter through the extension lines into an electrical signal, which is subsequently processed by the computer, producing the traces on the screen observed by the operator (Photo).

Pump tube. The pump tube allows the contrast medium to be carried into the bladder catheter. It is made up of three parts: first, a segment of the tube that goes inside the pump is made of silicone to resist the pressure exerted by the pump itself during bladder filling; the other two parts, the one connecting to the bladder catheter (which has a Luer Lock connector) and the one connecting to the contrast bottle, are made of PVC and are provided with a drip chamber.

Devices for electromyography. For the electromyography used during a VUMD test, two types of electrodes are available: (1) surface skin electrodes, generally made of silver/silver chloride (Ag/AgCl), capable of registering the electrical activity of perineal muscles, and therefore placed on the perineal skin on both sides of the region of the urethra; (2) needle electrodes (a concentric needle connected to the UDM apparatus by a single fiber cable), capable of detecting a small surface area from 0.02 to 0.07 mm². These needles are made of a stainless steel cannula and a core wire made of tungsten or silver.

4. Sequential steps of a videourodynamic

4.1 Clinical assessment of the patient

As mentioned above, performing a VUDM requires adherence to highly standardized procedures that include the use of specific materials, devices, and adherence to reproducible step sequencing. Before performing a VUDM, a complete and detailed clinical history of the patient must be collected. During this part of the clinical assessment, it is also essential:

- to understand the reason why the patient needs a VUDM; in fact, patients undergoing this diagnostic procedure should be carefully selected, and a proper balance between risks and advantages must be assessed. Videourodynamic should be considered only in cases where the information provided could become decisive for a definitive diagnosis and for therapeutic decision-making [16].
- to examine medical data provided by the patient (laboratory outcomes, results of previous imaging, and instrumental tests already performed); among

preliminary investigations, a bladder diary (frequency/volume chart, describing average voided volumes and micturition frequency) can add important data about bladder condition because it gives an objective report of patients' symptoms, allowing better management of the VUDM.

A complete history collection and physical examination must be performed before VUDM, and it should be done especially to evaluate the presence of contraindications to performing the diagnostic procedure; therefore, the physical examination must focus attention on the uro-genital system to reveal if there are anatomical or clinical findings that represent an obstacle, limitation, or risk. A urine examination with urine culture showing the absence of infection is usually required before VUDM to prevent the onset of severe urinary tract infection and possible upper urinary tract or systemic complications. It is important that patients receive adequate information about the VUDM. The medical doctor prescribing the VUDM must elucidate to patients the indication and, specifically, how the examination will be performed, with a detailed description of the preparation that requires bladder and rectal catheterize. This will improve the compliance of the patient and will also make the patient more collaborative during the procedure. Furthermore, being an invasive test with X-ray exposure, an informed consent must be shown to the patient and signed together with the clinician. Antibiotic prophylaxis is recommended, and it is based on different protocols that can be adopted differently based on guideline recommendations. Usually, trimethoprim-sulfamethoxazole (also in single dose), fosfomycin, cephalosporins, or fluoroquinolones are suggested [17, 18]. Some studies report that generally the use of antibiotics before VUDM is not recommended in the absence of well-known risk factors or in cases of negative urine culture [17]. However, in the literature, urinary infection is reported as a frequent complication of VUDM, and rare cases of urosepsis have also been documented, caused by gram-negative bacteria (especially *Pseudomonas Aeruginosa*) found either in the blood and urine of patients or in the urodynamic apparatus [18]. Therefore, we believe that the final consideration about antibiotic prophylaxis should be that clinicians have to carefully evaluate each single case and decide based on clinical data and risk factors. Aiming to prevent any problem during the recording of abdominal pressure through the rectal balloon catheter, an enema is recommended before the VUDM. In fact, the presence of fecal material in the rectum can obstruct the proper function of the rectal catheter and can determine the defecatory stimulus during the test, which can negatively influence the outcome. Another very important consideration about VUDM studies is to ensure the presence of both operators (usually represented by a dedicated nurse and medical doctor) during all the steps of the investigation, including history collection, physical examination, and test preparation, which includes bladder and rectal catheterize. Following the Good Urodynamic Practice, the examination should be carried out while maintaining interaction with the patient, allowing continuous observation of clinical symptoms reported and simultaneously paying attention to the signals coming from the instrument. This is even more important during a VUDM to decide when to start the pulsed radiologic setting and image capturing.

4.2 Preliminary free uroflowmetry

In all cases where it is possible, VUDM can be preceded by free uroflowmetry. Obviously, this procedure is not possible in catheterized subjects, in those who suffer

from bladder areflexia or have an atonic bladder, and in subjects who have a heterotopic urinary diversion. Patients are invited to urinate in a standing or sitting position, at their normal desire to void, and the results report the flow rate of the external urinary stream, which is measured in milliliters per second. The main parameters recorded by the uroflowmetry are the maximum flow, mean flow (calculated by dividing the voided volume of urine by the time of the voiding phase), and voided volume. An additional outcome is represented by the measurement of bladder residual volume, which can be assessed by pelvic ultrasound, bladder scanner, or (only in selected cases and when non-invasive methods are unavailable) by bladder catheterize. Although the VUDM test provides extensive data about bladder filling and voiding function, uroflowmetry is still considered an indispensable screening test in subjects suffering from lower urinary tract symptoms (LUTS). Therefore, it represents a significant step in a complete VUDM assessment, as it reflects the habitual voiding pattern of the patient. To enhance the diagnostic value of this preliminary investigation, patients should be asked to urinate at their normal desire, and privacy must be provided.

4.3 Final preparation of the patient and of the urodynamic apparatus

Patients should be placed in the most comfortable (physical and psychological) condition to perform VUDM. Preparation can be done with the patient in a lying position on a radiologic table or on an automated urological examination chair. Bladder and rectal catheterize should be performed by the same operator who will carry out the VUDM, as this phase can provide significant clinical information (e.g., bleeding, evidence of scarring, presence of obstacles in the urethral lumen or inside the anorectal region). Disinfection of the urethral external meatus is mandatory, as is the introduction of lidocaine gel at the beginning of the urethra. To reduce urethral sensation during the subsequent catheterization, the lidocaine gel should be inserted into the urethral meatus at least a few minutes before catheter insertion. After bladder catheterize, residual urine must be removed for two main reasons: (1) to obtain an exact measurement of the residual urine volume after free uroflowmetry; (2) to prevent dilution of the contrast medium that will be introduced into the bladder during video-cystometry. Once the patient has been prepared through catheterization and (when necessary) electromyographic devices, transducer balancing is recommended before connecting the catheters to the urodynamic apparatus. Good Urodynamic Practice requires balancing the urodynamic transducers before connecting the patient to the instrument, placing them at the level of the symphysis pubis. This procedure ensures accurate measurement of abdominal and vesical pressures. Despite these recommendations, there is still confusion regarding zero pressure and reference height. In urodynamic terminology, “zero” pressure refers to atmospheric pressure. When the operator balances the instrument at “zero” pressure, the transducer is open and completely disconnected from the patient’s catheters. The connection between the transducers and the bladder and rectal catheters should be made after balancing, using the upper edge of the symphysis pubis as the reference height. Unfortunately, in many centers, it is common practice to bypass some difficulties related to atmospheric balancing by balancing the transducers after connecting the patient to the instrument. This can lead to misinterpretation of outcomes, especially during the application of pressure/flow study “nomograms” and the definition of certain cystometric parameters (such as bladder compliance).

4.4 Procedure

Before proceeding with the VUDM, an X-ray of the abdomen must be taken. This first image aims to assess possible vertebral alterations that can induce the suspicion of pathological conditions of the spinal column, including congenital anomalies (myelomeningocele). Furthermore, it can reveal the presence of calcifications that have a vascular origin (phleboliths) or can be inside the urinary tract (stones). In addition, findings of previous surgery (clips, sutures, meshes) can be shown by this preliminary X-ray, and this can prevent diagnostic errors in the subsequent phases of the VUDM, after contrast medium is injected into the bladder. Then, the filling cystometry starts by injecting contrast medium at a standard rate of 50 ml/min, as recommended by the Good Urodynamic Practice. Patients suffering from neurogenic conditions, especially with symptoms suggestive of detrusor overactivity, may need a lower rate of infusion (20–30 ml/min). The filling phase is performed under fluoroscopic control to monitor bladder morphology, the aspect of the bladder neck at rest and during provocative tests (cough, Valsalva maneuver), and the presence or absence of vesicoureteral reflux. The patient is usually positioned in an oblique position, but it can be changed based on the needs of the investigator. Bladder filling can be stopped when the patient reports a strong desire to void (some studies suggest stopping this phase when the patient is uncomfortably full). Simultaneously, the following urodynamic parameters must be recorded: bladder compliance, presence/absence of detrusor overactivity, urinary leakage (spontaneous or provocative), cystometric capacity (maximum bladder filling volume achieved during filling cystometry), and electric activity of the perineal floor or external urethral sphincter in subjects undergoing simultaneous electromyography (basal activity, reflex activity during cough). The following step is represented by bladder voiding activity. The patient is asked to void the bladder after the command by the operator to optimize the fluoroscopic monitoring. During this part of the VUDM study, these parameters are observed: bladder neck opening, morphology and caliber of the urethra, presence/absence of vesicoureteral reflux, and bladder residual volume after completing micturition. At the same time, the following urodynamic data are collected: bladder, abdominal, and detrusor pressures (at the start of voiding and during the maximum flow), maximum and mean urinary flow, morphology of the urinary flow, and electric activity of the perineal floor or external urethral sphincter (which are physiologically relaxed during bladder voiding). In patients with bladder residual volume fluoroscopically detected, the amount should be checked by aspiration through the bladder catheter. After the study is completed, bladder and rectal catheters are removed, the patient is asked to report any problem or symptom related to the procedure, and is instructed to follow the recommendations regarding antibiotic prophylaxis and to inform the operators in case of complications (hematuria, urethral scarring, fever, pain, or other symptoms that may require medical attention). When the VUDM report is ready, the patient should be summoned, and the results should be discussed.

5. Clinical applications of videourodynamic

5.1 Neurogenic conditions in adults

Patients suffering from neurogenic conditions often experience LUTD. Symptoms and the type of dysfunction are both directly related to the site of the

neurological lesion. These conditions may lead to severe complications either in the bladder (and in men, the prostate) or the upper urinary tract (kidneys). Specifically, the loss of normal control of the bladder and urethral sphincters may be responsible for urinary incontinence and, in patients affected by spinal cord injuries of various etiopathogenetic origins, the onset of vesical-sphincteric dyssynergia, which can lead to high pressures inside the bladder. As a main consequence, inflammatory disease of the lower urinary tract may develop, along with vesical-ureteral reflux, which causes hydronephrosis, pyelonephritis, and, over time, chronic renal failure. For this type of patient, the contribution of VUDM is very important because the use of contrast medium can reveal, at the same time, the voiding pattern and morphologic findings that traditional UDM could not reveal, such as intra-prostatic and/or vesical-ureteral refluxes and bladder diverticula. Furthermore, in patients with urinary incontinence and vesical-ureteral reflux, the advantage of capturing the exact moment when the contrast medium passes through the bladder neck or goes up into the ureter can be related to functional outcomes (specifically detrusor pressures and external urethral sphincter activity), allowing for a precise pathophysiological diagnosis (**Figure 2**). There is extensive experience reported in the literature about



Figure 2.
Bilateral vesicoureteral reflux in a female patient with neurogenic detrusor overactivity due to multisystem atrophy.

the use of VUDM in neurogenic conditions. Many studies have focused their attention on patients with Parkinson's disease (PD) and Multi-Systemic Atrophy (MSA). In 2001, Sakakibara et al. reported the outcomes of an investigation using VUDM and sphincter motor unit electromyography in 29 patients with Parkinson's disease and 15 with MSA [19]. The study provided evidence that VUDM allows for the diagnosis of an "open bladder neck" at rest only in MSA subjects (53%), as a consequence of internal sphincter denervation. Moreover, this study assessed that the main functional alteration in these patients was detrusor hyperreflexia, which, in 93% of patients with MSA, was associated with neurogenic motor unit potentials, found only in 5% of PD patients. Therefore, this study allowed the authors to conclude that VUDM with external urethral sphincter electromyography could help not only to evaluate bladder function in patients with PD and MSA but also to contribute to the differential diagnosis between the two pathological conditions. These outcomes have been confirmed by other investigations [20–22]. Sakakibara et al., in 2001, reported the results of VUDM in 44 patients suffering from neurogenic conditions of different origins (PD, MSA, cervical spondylosis, cerebrovascular disease, multiple sclerosis, spinocerebellar degeneration) and concluded that VUDM better assesses failure of the external urethral sphincter closure and relaxation [23]. In this chapter, the authors advocated for the use of VUDM in more categories of patients, considering that, until that time, VUDM was applied only to patients affected by prostatic hypertrophy or spinal cord traumatic injury. As Sakakibara reported in this chapter, extensive data were already available about VUDM in patients suffering from spinal cord lesions and in subjects with spinal dysraphism, showing how the simultaneous use of radiologic assessment could improve diagnostic precision, allowing for better decision-making regarding therapeutic approaches and disease evolution [24, 25]. More recently, further data have been reported in the literature about VUDM in subjects with spinal dysraphism. In 2022, a retrospective study involving 181 patients assessed the helpful role of preoperative VUDM in predicting long-term postoperative voiding function in asymptomatic subjects [26]. Specifically, the authors have shown that patients with preoperative vesical-urethral synergy (spinal cord untethering) achieve faster spontaneous voiding and better urinary continence. A similar study was performed by Mazen A. Ghanem and collaborators, who retrospectively evaluated the preoperative VUDM outcomes of 24 myelodysplastic patients who underwent augmentation ileocystoplasty and concluded that a closed bladder neck diagnosed before surgery is an important predictive factor for postoperative continence [27]. VUDM can play an important role in the assessment of functional therapeutic outcomes in patients with neurogenic bladder dysfunction. One of the most commonly used therapeutic approaches for neurogenic detrusor overactivity is the injection of OnabotulinumtoxinA into the bladder muscle. Some authors have provided evidence that VUDM is the best tool to examine outcomes after Botox injection in patients with neurogenic detrusor overactivity [28]. A predictive role of VUDM has also been shown for patients who underwent OnabotulinumtoxinA injections in the external urethral sphincter due to neurogenic dyssynergia or detrusor underactivity [29]. A similar study has shown that VUDM has a good predictive role in subjects with neurogenic bladder dysfunction treated with antimuscarinic drugs or beta-3-adrenoceptor agonists [30]. Pathophysiological mechanisms of neurogenic bladder, when detrusor overactivity represents the main pattern, are responsible for an increased thickness of the detrusor muscle, with

consequent higher bladder weight due to the deposit of collagen [31]. In fact, the estimation of bladder weight has been considered, for many years, an indirect marker of detrusor overactivity of neurogenic and non-neurogenic origin [32]. A recent study carried out by the group of Misung Wang and collaborators has shown that the ultrasound-estimated bladder weight of patients suffering from neurogenic detrusor overactivity correlates well with VUDM outcomes [33].

5.2 Bladder outlet obstruction and non-neurogenic voiding dysfunction

The use of VUDM for the assessment of bladder outlet obstruction (BOO) is limited compared to the amount of data available for neurogenic conditions. Moreover, VUDM is not a recommended diagnostic tool for all patients suffering from BOO. However, various experiences have been reported in the literature by experts in the field. Sussman and collaborators, from New York University, have described the use of VUDM for the diagnosis of primary bladder neck obstruction, which represents a pathological condition characterized by “a functional obstruction secondary to abnormal opening of the bladder neck during bladder voiding” [34]. The authors report that, although uroflowmetry with post-void residual assessment, urethroscopy, and pressure flow studies can suggest this diagnosis, the role of VUDM allows a definitive impression due to the fluoroscopic visualization of the obstruction at the bladder neck level when the patient starts to void the bladder, associated with increased detrusor pressure recorded by the UDM transducer. Therefore, it is substantially accepted by the scientific community that primary bladder neck obstruction is a VUDM diagnosis and that VUDM permits a differential assessment with other conditions. For this reason, simple urodynamic parameters cannot support a diagnosis of primary bladder neck obstruction without the radiologic, simultaneous evidence of obstruction at the bladder neck level shown by the contrast medium. Various data are also available in women with voiding dysfunction, which can be related to anatomical or functional causes, such as detrusor underactivity, hypersensitivity of the bladder, dysfunction of the bladder neck or perineal muscles, and urethral sphincter dysfunction. Non-neurogenic dysfunctional voiding is the consequence of absent or lack of relaxation of the urethral sphincter or can be secondary to an altered coordination of the urethral sphincter during the bladder voiding phase [35]. Two important studies performed by Akikwala and Solomon, respectively on 153 and 535 women, support the role of VUDM for the diagnosis of primary bladder neck obstruction also in females, confirming urodynamic criteria proposed by Chassange and the following morphologic criteria that we report as originally described: “radiographic evidence of obstruction between the bladder neck and distal urethra in the presence of a sustained detrusor contraction, in presence of clinical assessment of obstruction” [36]. Another experience, on a smaller cohort, has been reported by Indian researchers, describing the use of VUDM to diagnose primary bladder neck obstruction in 10 women from a tertiary care center. In this study, the authors suggest that clinical assessment supported by VUDM represents the best diagnostic approach in women with suspicion of primary bladder neck obstruction [37]. The use of VUDM with external urethral sphincter concentric needle electromyography is recommended by some authors to diagnose Fowler’s syndrome, a condition first described by Fowler in 1986, affecting young females and characterized by urinary retention due to inadequate relaxation of the external urethral sphincter during bladder voiding [38]. However, there is still a lack

of studies on large populations that can provide definitive VUDM criteria for this pathological condition [39]. The role of VUDM in the diagnosis of obstructive patterns in women has been clearly described by Hann-Chorng Ku in 2005 [40]. This author reported an experience on 207 women, achieving a VUDM diagnosis of bladder outlet obstruction of various origins (urethral sphincter obstruction, pelvic floor muscle obstruction, high organ pelvic prolapse) in 19 subjects, showing that the different outcomes of the VUDM in women with BOO were well correlated with the underlying pathophysiology of bladder, pelvic floor muscle, or urethral dysfunction. The same author, together with other researchers, has suggested in another manuscript that VUDM contributes to therapeutic decision-making in women with dysfunctional voiding and that VUDM can help to predict treatment outcomes [41]. As already reported for neurogenic conditions, there is evidence also for dysfunctional voiding in women of a predictive role of VUDM in clinical response after onabotulinumtoxinA injection in the urethral external sphincter. A long-term follow-up study on 195 women reported that a significant obstructive profile at preoperative VUDM was correlated with favorable outcomes in terms of VUDM parameters and clinical assessment (bladder obstruction index scores) [42]. A significant report that has summarized all VUDM findings in women with voiding dysfunction was published in 2017 by Sheng-Mou Haiao and collaborators [43]. These authors collected VUDM outcomes in women from 1997 to 2015, and in this paper, they properly describe the VUDM technique, trying to propose a standardized approach. In this chapter, the authors compare radiologic and urodynamic patterns among different conditions that cause voiding dysfunction in women. they suggest that subjects experiencing BOO due to primary bladder neck obstruction usually show a detrusor pressure 30 cm H₂O with a closed bladder neck during voiding, while individuals suffering from dysfunctional voiding present intermittent urinary flow as the consequence of involuntary contractions of the periurethral striated muscle during voiding and urethral dilation to the level of the external sphincter with a wide-opening bladder neck. These authors concluded that VUDM findings should be adopted to guide differential diagnosis in women suffering from BOO. From these studies, various authors have noted that dysfunctional voiding in women increases with age and is associated with some comorbidities: central nervous system disease, blood hypertension, and diabetes mellitus [35]. A very interesting study described the use of VUDM with trans-rectal ultrasound for the assessment of women suffering from LUTS [44]. This experience focused on voiding disorders, and the authors, being urologists, had extensive experience with trans-rectal ultrasound. The cohort consisted of 62 women reporting LUTS, especially voiding difficulties, urinary urgency, stress urinary incontinence (SUI), and recurrent cystitis. The protocol included a VUDM study combined with pelvic electromyography (through surface electrodes) and trans-rectal ultrasound. This method allowed the investigators to compare morphologic outcomes achieved by contrast medium and fluoroscopy with anatomic findings found by ultrasound, including the assessment of the pelvic floor muscles, uterus, rectum, and urethra. The authors finally reported that this method allowed them to show pelvic floor anomalies in addition to VUDM findings, providing a more detailed pathophysiologic assessment, and described it as easy to reproduce and inexpensive. However, in our opinion, the results of this study need to be confirmed on a larger cohort of subjects. Moreover, it must be honestly considered that voiding the bladder could be partially impaired by the presence of a rectal ultrasound, which surely creates discomfort in a patient who has

already been subjected to bladder and rectal catheterize. Technically, it must also be recognized that the method presents some difficulties, as the rectal ultrasound probe is close to the rectal catheter, which could alter abdominal pressure recording, requiring frequent adaptations and corrections during the VUDM. Various studies report the assessment of men with BOO due to benign prostatic hyperplasia (BPH) by means of VUDM (**Figures 3–5**). Yuan-Hong Jiang and collaborators designed a study to examine the VUDM findings in men suffering from storage symptoms due to BPH [45]. This study included 614 patients suffering from urinary urgency undergoing medical treatment for BPH. The VUDM made a differential diagnosis among bladder neck dysfunction (22.3%), BPH (40%), detrusor overactivity (30%), and detrusor underactivity associated with detrusor overactivity (6%). These findings reinforced the concept that very often the clinical presentation does not necessarily correlate with BOO and that when patients do not improve their medical condition, second-line diagnostic methods, such as VUDM, represent a valid tool to achieve a correct diagnosis and therefore select adequate therapy. Specifically, the authors suggest performing VUDM in men who have persistent storage symptoms after medical treatment for BOO has started, supporting the adoption of the right treatment because of better pathophysiology comprehension. A similar study was performed by a group directed by Chang-Ling Lee on males suffering from detrusor underactivity [46]. The authors aimed to evaluate the results of therapeutic management in men with detrusor underactivity of neurogenic and non-neurogenic origin, based on clinical and VUDM patterns. Comparing the therapeutic outcomes and VUDM results, the authors concluded that this investigational tool allowed them to achieve a correct differential diagnosis of pathophysiological mechanisms of detrusor underactivity and to choose the appropriate treatment. Subjects with severe detrusor contractility impairment and absent bladder sensation were those with less favorable outcomes from conservative treatment, surgical approaches, and injection of onabotulinumtoxinA. Furthermore, they stated that, independently of the etiopathogenesis of detrusor underactivity, surgery provided the best efficacy.



Figure 3.
Large lateral bladder diverticulum and pseudo-diverticula in patient with decompensated detrusor muscle after BPH surgery.

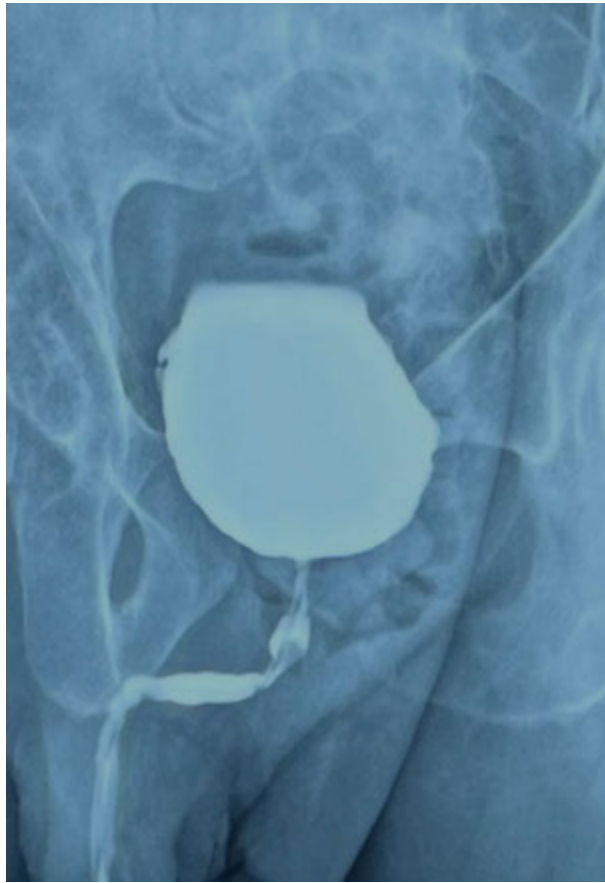


Figure 4.
Obstructed proximal urethra in a male with BPH. Pressure/flow study category: ICS obstructed.

A very large cohort investigation performed on 1,407 men supports the use of VUDM in the assessment of subjects with both non-neurogenic storage and voiding symptoms of the lower urinary tract [47]. The following conditions were shown: increased bladder sensation, detrusor overactivity, detrusor underactivity, association of detrusor overactivity and underactivity, as the consequence of bladder neck dysfunction, BPH, urethral sphincter pseudo-dyssynergia, and poor relaxation of the urethral sphincter. The outcomes of this study demonstrate how LUTS are often the expression of a complex association of pathophysiologic mechanisms and that in many cases, first diagnostic conclusions based on non-invasive methods can lead to erroneous interpretation and therapeutic failure. Interesting data are reported in the literature about micturition urethral pressure profilometry during VUDM [48]. In this manuscript, the authors describe the proper technique to obtain micturition urethral profile patterns during VUDM, providing data for various pathological conditions, such as BPH, bladder neck obstruction in men and women, urethral stricture, and neuropathic vesical-urethral dysfunction. Despite the evidence provided by these authors, the use of pressure profilometry during VUDM is not widely utilized because it requires significant experience both to perform the test and to interpret the outcomes, as well as the use of a trilumen catheter, which is

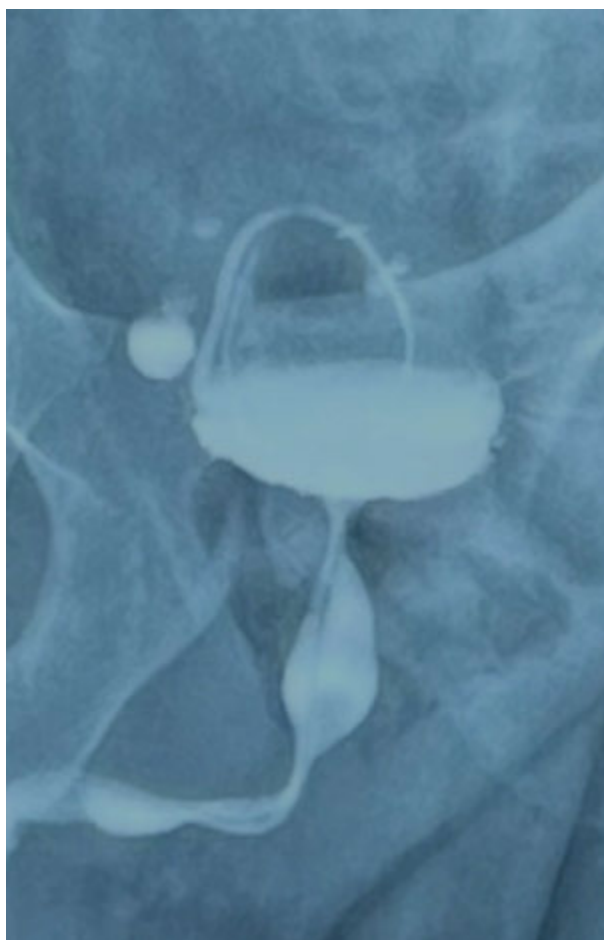


Figure 5.
Bladder diverticulum and pseudo-diverticula in a patient with obstructed proximal urethra due to BPH, associated with mild distal urethral stricture. Cystometric evidence of detrusor overactivity and pressure flow study suggestive for severe obstruction (IV Schafer/W + class).

not always available in all centers. However, clinicians should achieve confidence with this approach for selected cases.

5.3 Stress urinary incontinence

Stress urinary incontinence (SUI) is defined by the International Consultation on Incontinence as “involuntary leakage of urine during physical activities that increase abdominal pressure, such as coughing, sneezing, or exercising” [12]. Although this condition may affect both sexes, it is prevalent in women due to anatomic and functional reasons. Therefore, a large part of studies regarding diagnostic and therapeutic approaches has been conducted on female patients. From a clinical point of view, the diagnosis of SUI is based on symptoms reported, physical examination, and standardized questionnaires. Urodynamics allows for the determination of additional information that contributes to a better and more precise diagnostic assessment: bladder capacity, presence or absence of detrusor overactivity, bladder

compliance, and, most importantly, abdominal leak point pressures, which represent the value of pressures when urine loss is recorded. In fact, the abdominal leak point pressure provides information about the ability of the urethra to withstand abdominal pressure. The abdominal pressure associated with leakage of urine is inversely proportional to urethral weakness; a loss of urine under low abdominal pressures is indicative of severe urethral weakness. As reported by McGuire et al., the abdominal leak point pressure should be tested at moderate bladder filling, avoiding the induction of detrusor activity that can lead to misinterpretation of results [49]. Based on standard procedure, the patient should stay in a standing position with transducers at the symphysis pubis level. Then, the operator instructs the patient to perform a progressive Valsalva maneuver. Videourodynamics adds the advantage of identifying the exact moment when leakage starts, as the contrast medium passes into the proximal urethra at the opening of the bladder neck, and this event is more precise than the record provided by traditional UDM. In the case of a negative test, this can be repeated at increased bladder volumes until bladder capacity is reached. A negative test under this condition, with abdominal pressure up to 150 cm H₂O, allows for the exclusion of urethral weakness. The use of abdominal leak point pressure during UDM and VUDM has become of great importance because it helps to categorize the type of dysfunction. Although this test alone is not considered the sole clinical parameter for the decision-making process in terms of therapeutic choice, its contribution is very important. Referring to McGuire's indications, in female patients who do not have genital prolapse, a leak point pressure <65cm H₂O may indicate intrinsic sphincteric dysfunction, while leak point pressure values >100cm H₂O >100 cm H₂O is usually associated with urethral hypermobility. Patients presenting with abdominal leak point pressures between these two values may suffer from both urethral hypermobility and sphincteric deficiency [49]. The use of VUDM in subjects with genital prolapse also allows for the observation of the severity of the condition during the cough test and Valsalva maneuver and simultaneously achieves detrusor and abdominal pressure measurements. Bladder morphology, bladder neck position, urethral axis, and the vesical-urethral posterior angle can be compared by superimposing the different images captured at rest and during the stress tests. Hann-Chorng Kuo examined the relationship between Valsalva and cough leak point pressures in women with SUI, suggesting that these two provocative tests cause leakage of urine by different mechanisms and that VUDM is helpful in differentiating the pathophysiology of SUI. It represents the best diagnostic method to assess urethral function, Valsalva leak point pressure, cough leak point pressure, and bladder neck descent [50]. This retrospective experience involved 116 patients who underwent VUDM. All these data can be considered for better diagnostic assessment and to evaluate the outcomes of SUI surgery. Regarding this last aspect, Carbone et al. in 2002 reported the VUDM outcomes of patients who underwent the In-Fast bone-anchored procedure for SUI [51]. In this study, the authors clearly described the utility of VUDM investigation to preoperatively categorize patients and to verify the functional and anatomical results through postoperative VUDM. The results of this investigation support the importance of a standardized VUDM procedure to allow a correct pathophysiological classification of SUI. The procedure must follow Good Urodynamic Practice, and the position of patients must respect the indications suggested by McGuire. In fact, some authors have shown how SUI grade and classification may significantly change if patients undergo VUDM in different positions. Hazel Ecclestone and collaborators in 2018

submitted 72 patients to VUDM in both standing and lying positions, reporting that 40.5% of women had a changed Blaivas and Olson grade of SUI when evaluated in a standing condition compared to lying [52]. Another study that investigated postoperative outcomes in women who underwent surgery for SUI was performed by the group of Fei-Chi Chuang [53]. VUDM helped to show de novo detrusor overactivity in 18 patients and, at the same time, contributed to assessing morphological surgical outcomes. This report focuses attention on one important aspect of the postoperative follow-up of women who have undergone SUI surgery. In fact, in some patients, bladder irritative symptoms may be the consequence of mesh positioning, which causes mild obstruction to the urethra. The use of VUDM in the postoperative follow-up allows for better investigation of this aspect, thus enabling the selection of an adequate therapeutic choice. Patients with irritative symptoms, associated or not with detrusor overactivity but without significant BOO, may benefit from various treatment options, including drugs, various types of neuromodulation, or, in selected cases, onabotulinumtoxinA injections, while subjects with severe obstruction should be considered for surgical revision. These conditions are often not easy to manage in the postoperative period, and a valid diagnostic instrument is mandatory to prevent a wrong approach. Similar data about the use of VUDM to assess postoperative results of SUI surgery were reported by Hann-Chorng Kuo after an investigation on 14 women with SUI types II and III. The surgical procedure was represented by a pubovaginal sling, and VUDM was performed preoperatively and within 7–14 days post-surgical treatment [54]. In this study, VUDM diagnosed de novo detrusor overactivity in 2 subjects, confirming that this represents a possible postoperative functional complication of SUI surgery that can be properly assessed by VUDM. The simultaneous use of radiologic evaluation allows for a precise identification of the detrusor leak point pressure (detrusor pressure value at the start of leakage during detrusor overactivity). Some authors reported the usefulness of VUDM in evaluating therapeutic goals of pelvic floor rehabilitation for SUI. In 2003, a study exploring the use of VUDM in 40 women who underwent pelvic floor exercises to improve symptoms of SUI supported the utility of pelvic floor muscle training to strengthen pelvic floor muscles. It also demonstrated that VUDM with pelvic floor electromyography through surface electrodes was able to objectively compare pre and post-treatment conditions [55]. The important role of VUDM in the assessment of voiding disorders in women with SUI has also been shown by other studies. A retrospective analysis of 104 patients with SUI who underwent VUDM in the diagnostic evaluation revealed that 18.3% were affected by urodynamic and morphologic findings indicative of BOO [56]. In the group of obstructed women, the VUDM outcomes allowed for the establishment of a differential diagnosis between iatrogenic causes (previous anti-incontinence or anti-prolapse surgery), genital prolapse, neurogenic conditions, dysfunctional voiding, and idiopathic conditions (**Figure 6**). The authors, after discussing the outcomes of their study, remarked that SUI may coexist with BOO in women and that a proper diagnostic evaluation by VUDM is mandatory to avoid erroneous therapeutic choices [56]. Stress urinary incontinence may also arise from neurogenic conditions in both sexes and may have an iatrogenic origin (especially as a consequence of pelvic surgery). The VUDM has a significant role in these patients for a precise definition of condition severity and decision-making about treatment (from pelvic rehabilitation to anti-incontinence surgery). In these cases, the most important parameter that must be considered is the Valsalva leak point pressure. In the male population, SUI is mostly

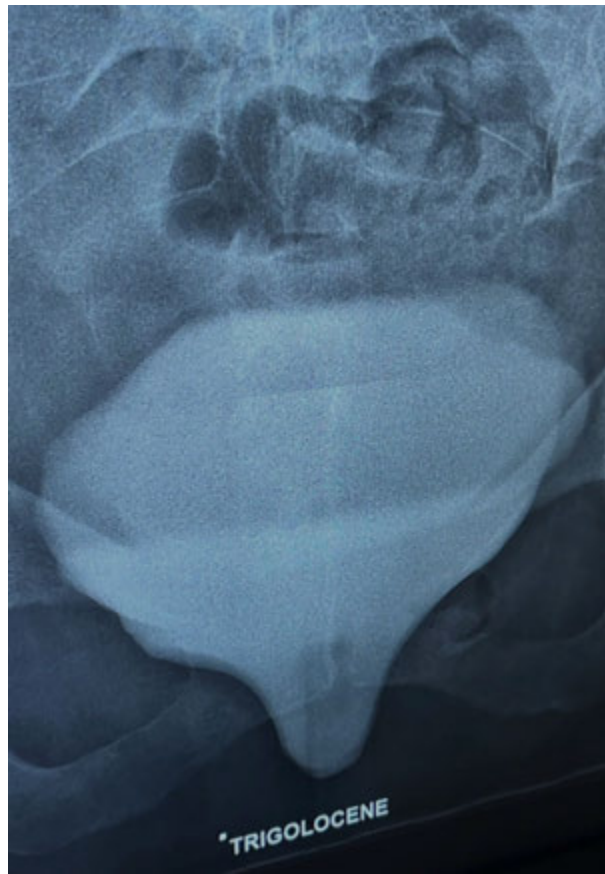


Figure 6.

Persistent bladder residual volume was observed even after catheter removal at the end of VUDM in woman with a trigonocoele that developed following a previous hysterectomy. Trigonocoele is a downward herniation of the bladder trigone. In this patient, cystometry data showed increased bladder sensation and pressure/flow study revealed an underactive detrusor.

the consequence of surgery, especially after prostatic interventions. The role of VUDM in the assessment of post-prostatectomy SUI and, generally, post-prostatectomy problems, has been shown by various authors. In fact, complications after prostatic surgery may include urinary incontinence as a consequence of detrusor overactivity or sphincteric deficiency, or voiding problems that are often secondary to stricture of the anastomosis between the bladder neck and the urethra or the urethra itself. VUDM is capable of providing adequate diagnostic evaluation of all these conditions, suggesting the best treatment options [4].

5.4 Pediatric patients

The VUDM has been largely used in pediatric population for the assessment of vesical-sphincteric dysfunction, especially in cases of malformations and neurogenic congenital disorders, aiming to achieve an exact pathophysiological diagnosis that includes the examination of the upper urinary tract. Urinary incontinence is one of the most frequent reasons for seeking medical assistance by pediatric subjects, and

the diagnostic protocol involves pediatricians, pediatric neurologists, pediatric nephrologists, pediatric urologists, and sometimes neuropsychiatrists. Persistent daytime urinary incontinence is a condition associated with reduced quality of life and is highly bothersome to patients and their relatives. Some papers suggest that the use of VUDM has improved the diagnostic and therapeutic approach to this condition, allowing a better comprehension of bladder and urethral function. Regarding this aspect, a retrospective study performed by Borzyskowski reported the results of VUDM assessment in 215 children with diurnal urinary incontinence [57]. The population was represented by subjects of both sexes, with ages ranging from 3 to 16 years, reporting diurnal wetting. VUDM showed various abnormalities: occult neuropathic bladder (presenting detrusor overactivity, hypersensitive bladder, or large-capacity bladder), bladder neck obstruction, and a previous history of congenital abnormalities such as urethral valves, urethral stenosis, and wide bladder neck anomaly. However, 8% of this population did not present any functional or anatomical anomaly, allowing for the diagnosis of a behavioral problem (patients did not want to void the bladder at school or outside their home). On the other hand, the fact that only a small part of the population had normal bladder function induces consideration that patients with persistent diurnal incontinence should be assessed with attention, and their clinical condition should never be underestimated. The VUDM studies are also helpful in children suffering from enuresis, as described by Arena et al. since 1996 [58]. Detrusor overactivity and vesical-sphincteric dyssynergia were the most important functional alterations found in this cohort, while bladder diverticula and vesical-ureteral reflux were the main anatomical outcomes. As these studies clearly report, in a large proportion of children presenting LUTS, congenital abnormalities are diagnosed. Nowadays, prenatal diagnostic screening through genetic assessment and ultrasound screening allows for the early recognition of many of these malformations. A large survey carried out on 422 children presenting LUTS and submitted to VUDM reported that normal bladder function was observed in 9% of patients [59]. Vesical-ureteral reflux was documented in 43% of children, detrusor overactivity in 31%, neurogenic bladder dysfunction in 35%, outflow obstruction in 3%, wide bladder neck in 4%, and vaginal reflux in 2%. The authors, in the discussion, commented that the selection of patients eligible for VUDM was based on history and non-invasive previous examinations and that VUDM represents a very important informative investigation in children with bladder dysfunction, particularly in those with neurogenic conditions, because it allows for the identification of reflux, bladder and bladder neck characteristics, and urethral abnormalities during filling and voiding phases, together with functional outcomes of the lower urinary tract. A very important study including a larger cohort of children was presented by the group of Hoebeke et al. [60]. This study, in 4 years of observations, collected VUDM outcomes performed in children after they were previously screened for LUTS by means of non-invasive diagnostic tools (uroflowmetry, ultrasounds, laboratory tests) due to urinary tract infections and small bladder capacity not responding to training. Outcomes they reported were represented by normal vesical-sphincteric function in 62 patients, urge syndrome in 582, dysfunctional voiding in 316, and “lazy bladder” in 40. Statistical analysis showed some differences among sexes: males with a “lazy bladder” were younger than those with urge syndrome and dysfunctional voiding, while females with dysfunctional voiding were younger than those with urge syndrome. No significant difference was found regarding vesical-ureteral reflux,

which was diagnosed in 15% of both sexes. Further support for the use of VUDM studies in children has been provided by other authors. Kakizaki and his collaborators suggest that children with LUTD deserve proper evaluation and that invasive UDM and VUDM should be mandatory in subjects in whom first-line therapeutic approaches fail [61]. In this category, VUDM plays a significant diagnostic role for the assessment of bladder reflux, which represents one of the most frequent abnormalities in young subjects, especially in neuropathic conditions [62]. On this topic, a prospective investigation during a 5-year period reported VUDM outcomes of 102 children [63]. The study showed that in 40% of patients, detrusor overactivity was found as the main cause of vesical-ureteral reflux, and the authors proposed VUDM as an easy and efficient diagnostic tool. Similar outcomes were found by Miguel L. Podesta et al. in 12 very young patients (median age 9 months) [64]. Other clinical applications of VUDM in children have been described in the literature. In 2021, the group of Sharon Mohan Kunnath presented an experience of using VUDM to assess giggle incontinence from a tertiary regional bladder unit [65]. A valid contribution of VUDM in the preoperative assessment of 41 children with urge syndrome eligible for transcutaneous neuromodulation has been described by Hoebeke et al. [66]; VUDM allowed for the identification and selection of patients feasible for the treatment and was predictive of favorable outcomes [66]. Another paper showing the contribution of VUDM for the assessment of outcomes of urologic treatments in children was presented by Ricardo Medel et al. This group compared pre and postoperative VUDM outcomes of 75 children with neurogenic bladder dysfunction secondary to myelodysplasia and submitted to augmentation cystoplasty [67]. In this study, the results suggest that, based on VUDM results, detrusor pressure during filling videocystometry represents the most reliable parameter to predict continence outcomes after the surgical procedure.

5.5 Other indications: Urinary diversion, kidney transplant, bladder inflammatory disorders, overactive bladder, frail elderly urinary incontinence, and bladder dysfunction

Patients submitted to radical cystectomy with orthotopic neobladder need a follow-up based on clinical recurrent evaluation, laboratory tests, and morpho-functional assessment of the reservoir. In fact, a series of complications may develop after this surgery and must be early recognized and treated: SUI, urgency incontinence, urinary retention due to voiding dysfunction, urethral and neobladder neck stricture, and neobladder-ureteral reflux. The simultaneous morpho-functional assessment of the neobladder in the postoperative follow-up is adequately provided by VUDM, and various papers support this evidence. In 1996, Carbone and Gezeroglu described the use of digital fluoroangiographic video-urodynamics in the follow-up of patients who had undergone urinary diversion [68]. In this study, the cohort was represented by 27 patients submitted to different types of bladder reconstruction: padovana ileal neobladder, Studer ileal neobladder, and Indiana Pouch. The authors reported that VUDM allowed them to evaluate the neobladder morphology and reservoir pressures during both the filling and voiding phases and to exactly correlate complications to functional or anatomic problems. The group of Sherif R. Aboseif presented the results of a study based on VUDM aimed at assessing continence mechanisms of the ileal neobladder in female patients [69]. The outcomes of this investigation, which included 10 patients submitted to a modified

radical cystectomy followed by bladder reconstruction using a 40 cm detubularized segment of ileum in a W-shape as proposed by Hautmann, supported the evidence that continence achievement in female diverted patients is based on the preservation of the intrinsic sphincteric mechanism and the surgical reconstruction of a low-pressure neobladder. These data confirmed previous experiences of other groups [70]. Some years after their preliminary report, Carbone and Gezeroglu, in collaboration with other colleagues, reported the VUDM outcomes of a larger survey on 101 patients submitted to Alcini's ileocecourethrostomy and ileal reservoir [71]. A detailed description of the VUDM technique for the assessment of urinary-diverted patients is reported, and its utility in recognizing complications is discussed. In the cohort examined, they found residual peristaltic activity as the main cause of leakage during VUDM and discovered neobladder-ureteral reflux in 12.5% of the population. Moreover, they showed how the use of VUDM with perineal muscle floor electromyography contributes to assessing how patients void the reservoir, helping clinicians adopt strategies to improve neobladder emptying and prevent complications that can develop in cases of severe urine retention. An interesting, more recent experience has been reported on the use of VUDM for the assessment of ileal neobladder achieved by a totally intracorporeal laparoscopic technique [72]. In this study, the authors examined postoperative outcomes of 50 male patients submitted to laparoscopic radical cystectomy with totally intracorporeal neobladder (U-shaped) reconstruction. The VUDM allowed them to establish the good functional outcome of the reservoir with a good morphologic aspect, showing residual peristaltic activity in 9 patients (6 presenting leakage), SUI in 5 patients, and ureteral monolateral reflux in 7 individuals. This preliminary experience, presented in 2015, suggested that surgical, functional, and morphological results achieved by the laparoscopic technique could be considered comparable with those obtained by traditional surgery. Since those years, minimally invasive surgery (laparoscopic and robotic) has grown over time, and nowadays, most urologic centers perform radical cystectomy and ileal neobladder reconstruction using these techniques. Limited experience is available in the literature about the use of VUDM in the follow-up of kidney transplant patients. In this type of patient, VUDM is required in selected cases of persistent symptoms that do not improve with first-line approaches, such as recurrent cystitis or recurrent inflammatory disease of the upper urinary tract. The utility of VUDM in kidney-transplanted patients was first described by Fernando Galbis Sanjuan and his group [73]. This was a pilot study including, respectively, 22 patients waiting for kidney transplant and 10 already transplanted, reporting LUTS during the follow-up. The VUDM showed bladder dysfunction associated with vesical-ureteral reflux in most patients with chronic renal failure waiting for transplant, while lower urinary tract obstruction was the main finding in the post-transplant cohort. The authors concluded by stating that some conditions should require VUDM before renal transplant: interstitial nephropathy with vesical-ureteral reflux, suspicion of significant BOO, urinary diversion, and neurogenic disease (**Figure 7**). experience is also reported with the use of VUDM in patients suffering from bladder inflammatory disorders. A pilot study describes the VUDM outcomes of patients suffering from interstitial cystitis-like symptoms; the main characteristics found in this condition suggest that BOO contributes to the development of a hypersensitive and painful bladder that affects these patients. However, the results come from a limited cohort and monocentric experience [74]. An interesting study has demonstrated that patients with chronic bladder inflammation may develop



Figure 7.

Evidence of vesicorenal right complete passive reflux in a young (35 years) female after transplant. The VUDM showed reduced bladder capacity and low compliance. The clinical pattern was represented by recurrent urinary tract infections. After one year following the kidney transplant glomerular filtration rate significantly decreased.

detrusor underactivity, which has been diagnosed by VUDM, and that this condition develops due to sub urothelial inflammatory disorder associated with sensory alterations and impaired signaling at the urothelium level [75]. Some data are also available regarding the use of VUDM in patients suffering from recurrent bacterial cystitis, suggesting that it may provide significant information to discover pathophysiologic mechanisms behind the infectious disease [75]. Some other data are available from the literature about the assessment of overactive bladder patients by means of VUDM. Although the studies are characterized by limited populations and cannot lead to definitive statements, authors suggest that VUDM is the only method to correctly assess urethral incompetence during bladder filling and, therefore, to identify those subjects who develop overactive bladder symptoms due to urethral-related syndrome [76]. Bladder dysfunction is a condition that generally increases with age. Aging of the world population will become a real challenge in the future, and therefore, many pathological conditions are expected to increase in incidence. In the elderly, urinary incontinence will be one of the most important problems requiring medical intervention, with a significant socio-economic burden. Specifically, in the frail elderly, urinary incontinence and general bladder dysfunction can be sustained by multiple etiopathogenetic factors, and some authors support the use of VUDM in this population, also to identify possible neurogenic conditions that are not clinically evident. However, for these patients, the risks and advantages of VUDM must be carefully considered [76].

6. Considerations

All the data reported above, which we summarized in **Table 1**, have shown the role that VUDM plays in the diagnostic assessment of LUTS, as reported by

Clinical conditions	Main VUDM outcomes	References
Neurogenic bladder dysfunction	VUDM allows the diagnosis of the type of neurogenic LUTD and contributes to identifying the lesional level of the nervous system based on the vesical-sphincteric pattern. VUDM is useful for treatment decision-making and can predict therapeutic outcomes in patients undergoing antimuscarinic, beta-3-adrenoceptor agonist therapies, and onabotulinumtoxin A injections. VUDM also allows the identification of complications in the upper urinary tract caused by neurogenic bladder dysfunction. Data are available for different neurogenic diseases: Parkinson's disease, Multi-System Atrophy, Spinal Cord Injury, vascular accidents, and congenital neurogenic conditions.	[24, 25, 21, 19, 23, 20, 22, 26, 29, 28, 30]
Bladder outlet obstruction (BOO)	VUDM makes proper assessment of BOO in men due to benign prostatic hyperplasia, bladder neck obstruction, urethral stricture, and in women with genital prolapse, bladder neck obstruction, and urethral stricture. In addition, functional syndromes secondary to altered behavior of pelvic muscles during micturition (including Fowler's syndrome) can be correctly diagnosed. Morpho-functional alterations related to these conditions can be revealed: detrusor overactivity and underactivity, damage to the bladder wall (diverticula), vesicoureteral and urethral-prostatic reflux, and vaginal reflux. High precision in identifying the site of BOO by VUDM has been shown.	[38, 44, 40, 47, 43, 34, 42, 37]
Stress urinary incontinence (SUI)	In women, VUDM contributes to the definition of the type of SUI, diagnoses the presence of concomitant voiding dysfunction, and provides morphologically significant information about the bladder and bladder neck at rest and during provocative maneuvers (cough, Valsalva). Determination of leak point pressure is more precise than traditional UDM due to the contribution of simultaneous fluoroscopy. Various studies show the predictive role of VUDM in the outcomes of SUI treatments (surgery and pelvic floor exercises). In men, VUDM enables a proper evaluation of post-prostatectomy SUI, and leak point pressures are suggestive of disease severity.	[6, 49, 48, 50, 56, 51, 53, 52]
Pediatric patients	VUDM is the best tool to assess LUTD in children. Large surveys show that the main pathological conditions are represented by persistent diurnal incontinence, recurrent urinary tract infections, voiding dysfunction, small bladder capacity, and lazy bladder. The most important findings shown by VUDM are represented by detrusor overactivity and vesicoureteral reflux. Congenital abnormalities and birth traumas are associated with neurogenic LUTD.	[62, 57, 58, 63, 60, 66, 67, 59, 64, 61, 65]
Orthotopic ileal neobladders	VUDM represents the best tool to assess the morpho-functional characteristics of ileal neobladders in clinical follow-up. VUDM outcomes provide information about the physiology of the reservoir, allowing the exclusion of alterations that can be responsible for the most frequent complications: urinary incontinence related to sphincteric deficiency or persistent residual peristaltic activity, neobladder ureteral reflux, high residual urine volume after neobladder emptying, and altered relaxation of pelvic floor muscles during the voiding phase. Favorable data regarding VUDM assessment of ileal neobladders performed by a totally intracorporeal procedure are present in the literature.	[68, 71, 72]

Bladder inflammation	In subjects with chronic bladder inflammatory disease, VUDM has revealed that BOO contributes to originating a hypersensitive and painful condition and that long-term inflammation may determine detrusor underactivity.	[75, 76, 16]
Kidney transplant	VUDM plays an important diagnostic role in patients with chronic renal failure who are waiting for a kidney transplant, with the goal of recognizing morpho-functional alterations of the lower urinary tract that contraindicate the transplant or must be improved beforehand. Literature suggests performing VUDM prior to kidney transplant in patients with the following conditions: interstitial nephropathy with vesico-ureteral reflux, suspicion of significant BOO, urinary diversion, or neurogenic disease. In transplanted patients with recurrent or persistent LUTS that do not improve with first-line therapeutic approaches, VUDM is mandatory to properly understand the underlying pathophysiology and exclude damage to the implanted kidney.	[73, 77, 76, 16]
Frail elderly urinary incontinence	VUDM can be adopted in frail elderly subjects because the underlying pathophysiology of LUTS may be complex and needs proper evaluation to establish treatment. Adequate balance between the risks and benefits of VUDM must be considered in these patients, and therefore compliance has been considered.	[78, 76]

Table 1.
Clinical applications, main videourodynamic findings, and references are summarized.

numerous studies in the literature. Lower urinary tract symptoms are considered indicative of LUTD, which is often complex and not always easy to cure. Non-invasive assessment of LUTS includes history, physical examination, voiding diary, uroflowmetry, voiding questionnaires, and ultrasound, which may provide a general idea of the pathophysiology underlying symptoms, allowing for first-line therapeutic indications. Persistent symptoms, recurrent conditions, and the development of complications should prompt reconsideration of the diagnostic algorithm, and second-line tools can be adopted. UDM and VUDM represent objective measures of lower urinary tract function and dysfunction. In a review written by Jiang et al. in 2020, VUDM was indicated as a “diagnostic instrument capable of providing deep insight for the LUTS in one only comprehensive test for complicated LUTDs” [76]. In fact, it is the unique method that combines functional and morphological information, which can be simultaneously and, most of all, in real-time achieved [76]. Therefore, there is a common consensus that VUDM can be considered mandatory when the initial management of LUTS does not provide efficacy. Very recently, the role, benefits, and optimal practice of VUDM, as well as its superiority over UDM, have been described in a publication by Mikołaj Przydacz and Howard B. Goldman [16]. In this chapter, the authors highlight not only the significant diagnostic contribution of VUDM but also its usefulness in the decision-making process. However, it is emphasized that VUDM should be considered a standard approach in the assessment of neurogenic conditions, in women with obstructive symptoms, and in cases of congenital abnormalities of the lower urinary tract. Another very important aspect is to respect optimal practices in performing VUDM, following standardized procedures that make the outcomes reliable and comparable. The superiority of VUDM compared to traditional UDM has emerged from the above

considerations and data already shown. Despite all this evidence, in a specific study carried out by Sana H. Ansari and Ayman E. Mahdy, VUDM is not considered superior to traditional UDM [77]. The authors argue that the role of fluoroscopy could be replaced by ultrasound, thereby eliminating the need for a VUDM investigation. However, this study has many limitations and cannot be accepted for a definitive judgment. In fact, the population is represented only by women, it is a monocentric trial, the design is retrospective, and it does not take into consideration many pathological conditions of the lower urinary tract. An expert opinion about the value of VUDM has been provided in an “Expert Corner” interview by Dr. Mikel Gray, Professor of Nurse Practitioner of the Department of Urology in Charlottesville, Virginia (US), who confirms the superior role of VUDM compared to traditional UDM for lower urinary tract function assessment. He explains that ultrasound cannot achieve the same precision due to various methodological and technical limitations, most of all related to the use of suprapubic or trans-rectal probes during micturition, which interfere with the examination. Additional data in favor of VUDM assessment comes from patients’ opinions. In a questionnaire-based study carried out by Harriette M. Scarpiero and collaborators, patients who underwent VUDM were asked to answer a series of questions about their compliance [78]. The questionnaire was divided into two parts: in the first part, given before the VUDM, the questions focused on expected anxiety, pain, embarrassment, and general apprehension, while in the second part, given after the VUDM, the questions focused on the overall experience and whether the patient would accept repeating the experience. The final judgment of the survey reported that VUDM was well tolerated, with moderate anxiety and discomfort that should not represent a barrier. As confirmed by these investigations, patients were shown to be not overly worried about radiation exposure. However, as already mentioned above, the highly standardized protocols achieved for performing VUDM have allowed for limiting fluoroscopy exposure, which is very low, especially when the examination is conducted by experts. As with many invasive diagnostic tools, VUDM has required adaptations during the pandemic era. Hashim Hashim, in 2020, provided some suggestions for adapting Good Urodynamic Practice in cases of patients suffering from contagious conditions, as represented by COVID-19 [79]. The authors first suggest balancing the risks and advantages of VUDM in cases of patients with highly contagious conditions, categorizing them into high, intermediate, and low priority. Then, they provide a guide concerning patient risk assessment, the route into the department to reach the room for VUDM, personal protective equipment, physical distancing during VUDM performance, and how to manage coughing and Valsalva maneuvers. Some technical aspects of this investigational tool should improve in the future, considering the possible contribution of Artificial Intelligence, which is growing in every medical field. In 2023, Courtney Shepard Streur presented, in a short publication, some data that outline a possible scenario for the future application of Artificial Intelligence in interpreting VUDM outcomes. Data extracted from preliminary models are promising regarding accuracy in diagnosing types of bladder dysfunction after the examination of pressure-flow tracing and fluoroscopic images [80]. It is also possible to imagine that, in the future, a better understanding of the pathophysiology of bladder dysfunction, combined with machine learning, will allow for limiting the use of invasive instruments to achieve a correct diagnosis and establish the appropriate treatment.

7. Conclusions

Data available allows us to conclude that VUDM is a diagnostic tool capable of providing the best assessment of bladder function and dysfunction, showing its superiority compared to traditional UDM. Being a minimally invasive method, clinicians must carefully select patients, balancing risks and advantages. Furthermore, VUDM requires adherence to standardized procedures to prevent possible technical and methodological errors that might lead to diagnostic mistakes; therefore, proper preparation of personnel should be mandatory.

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Chapter 4

The Role of Radiology in the Assessment of Urinary Incontinence and Related Conditions: Focus on Complex and Refractory Cases

Nicole Zhang and Zhongxia Hu

Abstract

Urinary incontinence (UI) is a widespread yet often underestimated condition that affects millions of individuals worldwide. It significantly impacts quality of life, physical health, and psychological well-being. Although UI is typically diagnosed clinically, imaging is playing an increasingly important role in the diagnostic evaluation. This chapter offers a comprehensive overview of UI across the care continuum, with a special focus on interventional radiology (IR) as a supportive strategy in selected complex scenarios. It also explores the expanding role of diagnostic imaging in evaluating contributing conditions such as bladder outlet obstruction, hydronephrosis, and fistulas. IR is framed as an important adjuvant for the management of UI in certain cases. UI can be the primary condition, or UI may be a symptom of more serious underlying pathologies. In such cases, IR may provide minimally invasive solutions that support resolution. A holistic, multidisciplinary approach is emphasized throughout, integrating the critical role of nursing in assessment, referral, and patient-centered coordination of care. By doing so, the chapter advocates for comprehensive, individualized evaluation and management strategies tailored to the complexity of each UI presentation.

Keywords: urinary incontinence, diagnostic radiology, interventional radiology, nursing, multidisciplinary care

1. Introduction: Urinary incontinence (UI) in the context of diagnostic and interventional radiology (IR)

Urinary incontinence, defined as the involuntary leakage of urine, is a common and burdensome condition affecting millions worldwide. Beyond its impact on quality of life, UI contributes substantially to healthcare costs, institutionalization, and caregiver burden [1–3]. Although most cases can be managed with standard

approaches such as behavioral therapy, pharmacologic interventions, and surgery [4], these strategies are often inadequate in complex or refractory presentations, where underlying structural or functional abnormalities remain unrecognized.

Traditionally, the assessment of UI relied heavily on history, physical examination, and symptom-based classification [4]. While these methods remain essential, they can miss secondary causes that alter both prognosis and treatment. Increasingly, diagnostic imaging has proven valuable in clarifying such causes. For example, ultrasound allows the assessment of bladder wall thickness, postvoid residuals, and hydronephrosis; CT and MRI can identify obstruction, mass lesions, or fistulas; and videourodynamic studies provide critical insights into bladder outlet function [5–7]. These modalities not only complement clinical assessment but often reveal pathologies that determine whether conservative therapy will fail or succeed.

Interventional radiology further extends the care continuum by offering minimally invasive procedures tailored to complex cases. Balloon dilation and stenting can relieve urethral or ureteral strictures, embolization may control refractory urinary leaks or fistulas, and nephrostomy tubes preserve renal function in severe obstruction. These interventions do not replace urologic or surgical standards of care but serve as adjunctive solutions when conventional therapies are insufficient.

This chapter, therefore, focuses on the evolving role of diagnostic imaging and IR in UI. Rather than presenting a broad overview of continence care, we emphasize how imaging modalities and IR procedures clarify etiology, guide management, and support outcomes in difficult or refractory cases. A multidisciplinary perspective underpins this discussion, highlighting not only the technical contributions of radiology but also the role of nurses in assessment, referral, and coordination of patient-centered care.

2. Factors contributing to complexity and refractory cases

While UI can often be managed with conservative measures, certain factors contribute to complexity, treatment resistance, or misdiagnosis. These cases are the ones most likely to require advanced diagnostic evaluation and IR input.

Mixed urinary incontinence (MUI): Patients presenting with both stress and urgency symptoms often respond inconsistently to standard therapies. MUI is particularly challenging because overlapping mechanisms obscure etiology, necessitating imaging or videourodynamic studies to delineate the dominant driver of symptoms [4].

Anatomical and structural abnormalities: Conditions such as bladder outlet obstruction (BOO), urogenital fistulas, or pelvic organ prolapse frequently complicate management. These abnormalities are not always apparent on clinical examination but can be clarified with ultrasound, CT, or dynamic MRI. Identification of these lesions is crucial, as they often determine when IR interventions, such as embolization of fistulas or stent placement for obstruction, are indicated.

Neurological and systemic comorbidities: Neurogenic bladder secondary to stroke, multiple sclerosis, Parkinson's disease, or diabetes often results in refractory symptoms that do not improve with standard pharmacologic therapy. Imaging may reveal upper tract changes (hydronephrosis, renal compromise), prompting earlier referral for procedural intervention.

Postsurgical or iatrogenic factors: Anti-incontinence surgeries, prostate interventions, or reconstructive procedures may create strictures, leaks, or persistent dysfunction. These patients often benefit from IR procedures such as balloon dilation, nephrostomy placement, or targeted embolization.

Taken together, these factors illustrate why some patients progress beyond routine management into complex or refractory categories. It is precisely in these situations that advanced imaging and IR techniques provide the diagnostic clarity and therapeutic alternatives needed to optimize outcomes.

3. Role of diagnostic radiology in evaluation of UI

Diagnostic radiology is one of the modern pillars in the diagnostic evaluation of UI. In many situations, diagnostic imaging studies provide a definitive explanation for the causes of UI by detecting anatomical and, sometimes, functional abnormalities. Diagnostic radiology can also be used to plan procedures and surgeries that treat UI.

There are multiple different forms of diagnostic imaging examinations, utilizing different physical principles and mediums, such as sound waves, ionizing radiation (Xray), and electromagnetic waves/magnetism (MRI). In general, ultrasound and plain film are used for initial workups due to their good sensitivity and safety profile, while computed tomography (CT), magnetic resonance imaging (MRI), and fluoroscopic functional examinations are used for advanced workups and troubleshooting due to increased cost, the need for potentially harmful ionizing radiation, and their more invasive nature. **Table 1** summarizes commonly used diagnostic tools, highlighting their roles, advantages, and constraints in the assessment of complex or refractory cases.

Tool	Role	Notes/limitations
Ultrasound	Assessment of the kidney, bladder, residual volume, hydronephrosis, and renal stones; specialized pelvic approaches (translabial in women, transperineal in men) can assess the bladder outlet, pelvic floor, and prostate.	Pro: Noninvasive, widely available, functional imaging possible. Cons: limited for ureters, relies on expert sonographers.
CT	Identify masses, stones, obstructions, and other anatomical abnormalities.	Pro: Widely available, fast scan time, best anatomical evaluation. Cons: Radiation exposure; often need to administer contrast (potential renal damage, contrast allergy).
MRI (dynamic fast sequences)	Problem-solving with good soft tissue contrast resolution, functional and anatomical detail in complex UI.	Pro: Best soft tissue resolution. Cons: Emerging evidence (Manganaro et al.) requires concentrated expertise that may not be as widely available. It also requires expensive equipment and a long scan time.
Videourodynamic Studies	Functional assessment of bladder outlet and detrusor activity	Pro: Functional study, highly informative in refractory cases. Con: Invasive, requires expertise and patient cooperation.

Table 1.
Diagnostic tools for complex and refractory cases of UI.

Urinary incontinence can be evaluated by medical imaging. As of 2025, the most commonly performed diagnostic clinical medical imaging, such as CT, ultrasound, and MRI, provides extensive information in anatomical detail but limited functional details. Some examinations do provide excellent functional details via fluoroscopy but do not provide cross-sectional or soft tissue anatomical details, aside from anatomical details of the urinary conduit itself via contrast excretion. MRI is also able to provide real-time anatomical as well as functional details, but its usage for functional evaluation is largely experimental.

Bladder outlet obstruction may be caused by a wide variety of both functional and anatomical causes, with different causes sometimes depending on the biological sex of the patient. Postoperative transgender patients may also present special challenges due to altered urinary system anatomy and the potential for postsurgical complications leading to BOO.

In general, should imaging be necessary, the more routine imaging modalities will begin a workup for BOO, with the more functional/invasive/specialized examinations, such as voiding cystourethrography and intravenous urography, typically reserved as troubleshooting tools due to the added resources required.

Since any anatomical disruption along the entire collecting system, from the renal pelvis to the penile meatus/urethral opening, may lead to urinary obstruction, an imaging examination with a wider field of view and better cost-effectiveness is used initially to exclude obvious anatomical abnormalities not visible on physical examination. This examination is most often ultrasound or CT (noncontrast and contrast-enhanced). Intravenous pyelogram (IVP), the previous gold standard in urinary imaging, has largely been supplanted by the IVP protocol in CT. MRI can sometimes be used, as MRI can better characterize mass lesions and uses no radiation.

Urinary outlet obstruction can arise from both anatomical and functional causes. Common anatomical etiologies include iatrogenic changes following anti-incontinence surgery, periurethral masses (benign or malignant), pelvic organ prolapse, or congenital structures such as posterior urethral valves. Functional causes, such as sphincteric dyssynergia, may not produce a discrete block but still interfere with urinary flow, often leading to secondary changes in the bladder or upper tract.

Diagnostic imaging plays a central role in identifying these patterns. Ultrasound, CT, MRI, and contrast-based studies can help determine:

- whether an obstruction is present
- where it is located
- whether it is structural or functional
- whether secondary effects such as bladder wall thickening, hydroureter, or hydronephrosis have developed

Cross-sectional imaging modalities (CT and MRI) are especially helpful in evaluating complex anatomy and mass effect. Contrast studies such as CT IVP or voiding cystourethrography can also reveal functional obstruction, filling defects, or urinary reflux. In severe cases, new hydronephrosis in a symptomatic patient may indicate infection or sepsis and requires urgent decompression.

Urinary infection and fistula are additional scenarios in which imaging is essential. Clues such as bladder wall thickening, perivesical inflammation, or gas in the urinary bladder, particularly without recent instrumentation, raise concern for infection or a fistulous connection.

3.1 Overview of ultrasound in UI

Renal ultrasound is one of the common sonographic examinations performed and has been used as a diagnostic test for many decades [8]. The most common protocol for renal ultrasound evaluates both kidneys and the urinary bladder. If a patient has a transplanted kidney, that can be evaluated as well.

Due to the intrinsic characteristics of ultrasound, solid organs such as the kidney and fluid-containing organs such as the bladder are optimally evaluated, whereas tubular structures or organs that contain gas are not optimally evaluated since the air/water interface causes difficulty with the transmission of ultrasound and sonographic imaging. Moreover, small structures with similar transmission characteristics of sound may not be well visualized due to inherent contrast resolution limitations of the ultrasound system and the human visual system of the interpreting clinician.

Given the limitations mentioned above, certain structures are not optimally visualized with ultrasound. For example, ureters are almost never visible unless grossly enlarged; in such cases, the most cranial portion near the kidney and the most caudal portion near the bladder may be seen. In patients with a urostomy, evaluation of the urostomy itself is challenging with ultrasound due to its anatomical location and the presence of nearby bowel gas.

Overall, ultrasound is most often used as an initial imaging modality in the evaluation of UI to exclude anatomical abnormalities of the kidney, specifically hydronephrosis and/or stones.

Renal ultrasound is usually very tolerable, with a straightforward examination for patients and sonographers alike. No special preparation is required, except holding urine for a prevoid bladder examination. The native (nontransplanted) kidneys are best visualized with transducers placed at the bilateral flanks, and the kidney is examined in both the longitudinal (along the long axis) and axial (along the short axis) positions. Depending on operator preference, the urinary bladder may be examined before or after the examination of the kidney from the anterior pelvis. Some ultrasound protocols call for a prevoid and postvoid examination of the bladder and possibly the kidney, especially for the evaluation of urinary retention or incontinence. In this case, a postvoid residual volume of urine in the bladder can be imaged or calculated. The transducers used in adults are typically curved-array low-frequency transducers, while linear-array high-frequency transducers are used in pediatric patients, which produce higher fidelity while sacrificing tissue penetration [9].

In the longitudinal plane, the kidney is shaped like a kidney bean. It is seated within echogenic (bright) perirenal fat and has an outer parenchyma and an inner renal sinus. The renal sinus contains the urinary collecting system, such as the calyces, renal pelvis, fat, and major intrarenal blood vessels. Normally, the collecting system cannot be visualized. The outer parenchyma is made up of the outermost cortex and inner medullary pyramids. The average adult kidney is 10–12 cm long [5]. The normal cortex is about as echogenic as the liver or spleen unless liver disease or kidney disease is present. Chronic medical renal disease tends to make the renal cortex more echogenic, and fatty liver tends to make the liver more echogenic.

Ultrasound machines have several imaging modes. B-mode, or brightness mode, produces the black-and-white two-dimensional images that lay people and

clinicians alike are most familiar with and are used to evaluate anatomy. Doppler examination, on the other hand, evaluates blood flow within an organ. The main renal artery can often be imaged if the technical conditions are optimal (e.g., no bowel gas in its way, no large amount of tissue between the probe, which degrades image quality). An elevated velocity of over 180 cm/s is a predictor of more than 60% renal artery narrowing [10]. An altered waveform, called the Tardus Parvus waveform, in the renal artery can also suggest narrowing or a clot within the renal artery.

While the most commonly used form factor of ultrasound is a handheld probe shaped similar to a handheld phone, specialty probes exist in different form factors, such as endocavitary probes that are shaped like a long wand. These probes are used to perform transvaginal or transrectal examinations. These examinations are more invasive, but thanks to the high-frequency probe on the endocavitary probe, they are able to resolve structures with higher spatial resolution. These probes are useful in the evaluation of pelvic anatomy as well as for performing interventions in the pelvis.

Common findings with renal ultrasound include medical renal disease with increased parenchymal echogenicity [11], renal masses which may be solid or cystic, with solid masses frequently malignant, such as renal cell carcinoma [12], hydronephrosis or abnormal dilation of the renal collecting system, and renal calculi or stones.

Stones reveal themselves as discrete objects, with some artifacts visible occasionally. The twinkle artifact is visible on color Doppler and is highly sensitive for renal stones. On B-mode, renal stones are often visible with shadowing below. **Figure 1** demonstrates an ultrasound with a kidney stone.

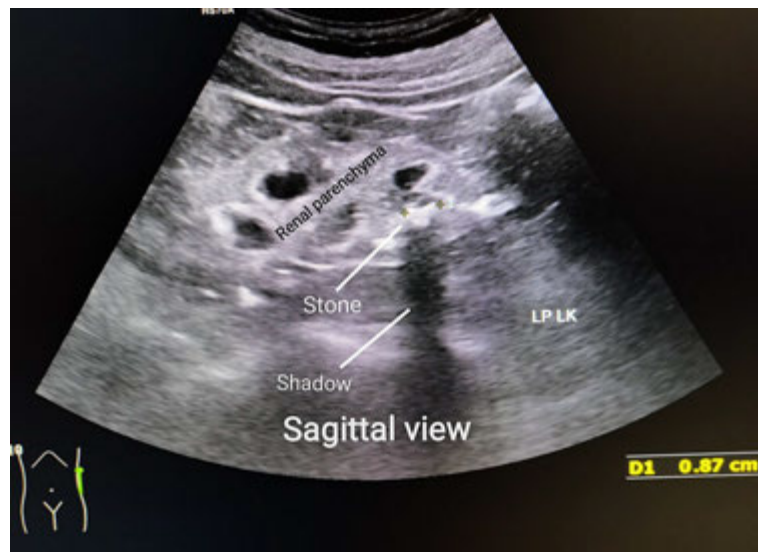


Figure 1.

Ultrasound of the lower pole of the left kidney showing a kidney stone with posterior acoustic shadowing; the renal cortex appears echogenic, suggestive of renal parenchymal disease. [Cerevisiae. Ultrasound of left kidney lower pole with stone [Internet]. Wikimedia Commons; 2022 Jan 13 [cited 2025 Sep 11]. Available from: <https://commons.wikimedia.org/w/index.php?curid=114249832>].



Figure 2.
Ultrasound of the right kidney demonstrating moderate hydronephrosis, evident by dilation of the renal pelvis and calyces due to urinary obstruction. (Cerevisiae. Ultrasound of the right kidney demonstrating moderate hydronephrosis [Internet]. Wikimedia Commons; 2022 Jan 5 [cited 2025 Sep 11]. Available from: <https://commons.wikimedia.org/w/index.php?curid=114013627>).

Hydronephrosis is visible as an anechoic (black) and dilated collecting system within the kidney. **Figure 2** demonstrates an example of a kidney ultrasound with hydronephrosis. Various grading systems exist, but the reporting of hydronephrosis is most commonly based on subjective evaluation and radiologist experience. In general, the more dilated the collecting system appears under imaging and the more thinning of the renal cortex is present, the more severe the hydronephrosis. A classification for the severity of hydronephrosis is shown in **Figure 3**.

Ultrasound has earned a unique place in the evaluation of UI, partly due to the advent of three-dimensional and four-dimensional reconstruction, which allows for a more intuitive anatomical evaluation of pelvic structures as well as the enablement of dynamic/temporal resolution of structures, and also because certain meshes/slings can only be well visualized under ultrasound.

Translabial ultrasound uses a standard curved array (abdominal imaging type) probe, which is widely available. Like its namesake, the probe is placed on the perineum. This technique allows imaging of the symphysis pubis, urethra, bladder neck, vagina, cervix, rectum, and anal canal. Intracoital or transvaginal ultrasound is performed via a transvaginal probe and allows for a greater field of view and better soft tissue resolution, albeit with more invasiveness due to the necessity of inserting and maneuvering the probe inside the vagina.

Stress UI occurs due to the inability to maintain a pressure differential between the bladder and urethra. Ultrasound is well-suited for the evaluation of physiology and anatomy in this area. It can evaluate the dynamic movement of the bladder neck and urethra during the Valsalva maneuver. Funneling of the bladder neck, seen on

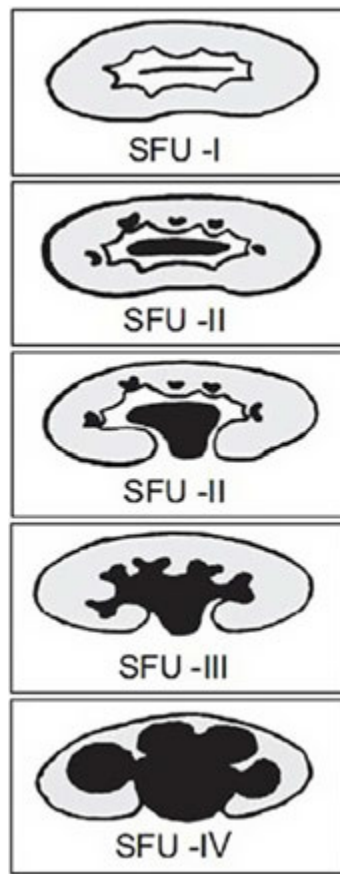


Figure 3.

Common grading scheme for hydronephrosis. Society for Fetal Urology grading system for hydronephrosis, illustrating the classification of dilation severity in pediatric renal ultrasound. [Article authors: Jose de Bessa Jr et al. Society for Fetal Urology (SFU) grading of hydronephrosis.jpg [Internet]. Wikimedia Commons; 2018 May 18 [cited 2025 Sep 13]. Available from: <https://commons.wikimedia.org/w/index.php?curid=78485756>].

ultrasound, suggests poor anatomical support. Ultrasound can also reveal the placement and location of vaginal mesh or graft in female patients with prior pelvic repairs and can evaluate whether the position and function are appropriate. While the evaluation of genitourinary fistula is not optimal with ultrasound due to the lack of contrast, sometimes such fistulas can be visualized via color Doppler due to the presence of a color jet from urine flow [13].

Translabial/transvaginal ultrasound is highly effective in the evaluation of mid-urethral sling (MUS) due to the highly echogenic appearance of MUS under ultrasound, making it easy to detect and evaluate. Using 3D/4D technology, the configuration and movement of MUS over time may be explored by ultrasound. An optimal configuration and location of MUS has been noted on ultrasound, with MUS changing from flat at rest to C-shape upon straining, and its location within the relatively mid-portion of the urethral length is considered optimal. Complications after placement of MUS may also be evaluated, with a good detection rate for

postoperative hematoma or abscess. Evaluation of inflammation remains better with MRI [14, 15].

Bulking agent injection, another method to treat stress UI, can also be evaluated with translabial/transvaginal ultrasound, as they are also visible [16].

Transperineal ultrasound is a technique used in men to assess the prostate by placing the ultrasound probe on the perineum, the area between the scrotum and anus. With the patient in a supine or lithotomy position, the transducer is angled cranially so that sound waves pass through the perineal tissues to visualize the prostate gland. This approach provides detailed views of prostate size, volume, and internal structure while avoiding the rectum, thereby lowering the infection risk. It is particularly valuable for guiding prostate biopsies, especially in the anterior and apical regions that are difficult to access with transrectal ultrasound [17].

3.2 Plain radiography (Xray/IVP)

Plain radiograph does not have the highest sensitivity or specificity for anatomical disruption seen in UI, except in stone disease, but it is quite affordable and widespread, so it is often one of the first imaging modalities obtained to evaluate organic causes of UI.

IVP, on the other hand, is very sensitive and specific for many anatomical causes of UI. However, it is considered to be more invasive as IV contrast administration is needed. It is also mostly replaced by cross-sectional imaging, such as CT-IVP, for almost all but the most resource-poor settings. There are still specialty indications for regular IVP; however, it is rarely associated with UI.

A regular plain film cannot examine the internal configuration of the urinary collecting system unless contrast has been administered, which would, by definition, turn this examination into an IVP. Essentially, the only common finding it can reveal in the setting of UI would be the presence of a renal stone. Even then, the sensitivity and specificity are often limited, with sensitivity degraded by overlying bowel gas and stool, and specificity limited due to the presence of other calcifications, such as vascular calcifications. Larger stones, such as staghorn calculi, are readily visible and are quite specific when spotted on plain film (**Figure 4**).

On IVP, anatomical disruption of the urinary collecting system and ureters is readily apparent, either as intrinsic obstruction or irregularity of the collecting system from a mass within, or extrinsic obstruction due to extrinsic mass effect, which often produces smooth tapering of the ureters. Urinary leaks are readily identified. However, overall, the sensitivity and specificity of IVP are inferior compared to cross-sectional imaging such as CT IVP, since intrinsic tumors within the collecting system are revealed by the absence of contrast in a 2D pattern, and extrinsic mass only appears as an impression upon the collecting system. As an example, **Figure 5** depicts IVP with the presence of a nephrostomy tube (antegrade nephrostogram), patent ureter, and moderate hydronephrosis of the kidney.

IVP may also reveal an abnormal configuration of the bladder, but it provides less detail compared to 3D cross-sectional imaging. It is capable of revealing urinary retention, though typically as an incidental finding.



Figure 4.

Abdominal KUB (kidneys, ureters, bladder) radiograph showing a large staghorn calculus occupying the renal pelvis and major calyces in a patient with severe scoliosis. [Nevit Dilmen. Staghorn kidney stone 0.8779.jpg [Internet]. Wikimedia Commons; 2002 [cited 2025 Sep 12]. Available from: <https://commons.wikimedia.org/w/index.php?curid=1374942>].

Hydronephrosis is invisible on plain radiographs but visible on IVP. The appearance is very pathognomonic and essentially looks like a glove filled up with water. Depending on the degree of obstruction and chronicity, the ureter may be dilated as well, and that is termed hydroureter.

New hydronephrosis in an ill-appearing, febrile patient is highly concerning for sepsis and pyelonephritis until proven otherwise. This is a life-threatening finding and may require an immediate decompressive procedure, such as nephrostomy of the affected kidney.

Urinary fistulas are invisible to plain film but are particularly well visualized by IVP due to the nature of the examination, as only urine is visualized in this examination, and even small leaks stand out with excellent contrast resolution with IVP. Due to the physics behind radiography, it can achieve a higher spatial resolution in 2D, even compared to CT. However, since IVP does not produce 3D images of the human body, it is less effective at localizing the leak in relation to other anatomical structures. IVP and CT IVP may both be used to investigate and localize a difficult-to-visualize fistula.



Figure 5.
Xray of a left kidney nephrostomy in a 50-year-old woman after contrast injection, showing the catheter tract and renal collecting system opacification. This is called an antegrade nephrostogram, an invasive procedure often performed by interventional radiologists. An IVP may produce a similar image from contrast found within the urine alone. [Jmarchn. Nephrostomy, case 1, Xray 2.jpg [Internet]. Wikimedia Commons; 2015 Dec 1 [cited 2025 Sep 12]. Available from: <https://commons.wikimedia.org/w/index.php?curid=132102021>].

Urinary tract infection is a common indication for imaging. Unfortunately, UTI cannot usually be visualized on plain radiographs, with some exceptions. Xanthogranulomatous pyelonephritis, or XGP, is a rare and severe form of chronic pyelonephritis with a nonfunctioning kidney. On plain film, it may be visualized as a staghorn calculus, possibly with fragmentations. Emphysematous pyelonephritis, a life-threatening, gas-forming renal infection, is readily visualized on plain film due to the contrast resolution produced by air bubbles within the kidney.

3.3 Computed tomography

Computed tomography, or CT, strikes the perfect balance between the widespread availability of equipment and interpretation expertise, as well as the provision of some of the most extensive anatomical information that may be provided in an imaging study within a large field of view. CT can evaluate a wide variety of diseases outside of the urinary system as well, and it may be one of the few examinations available after hours in an emergency setting due to the

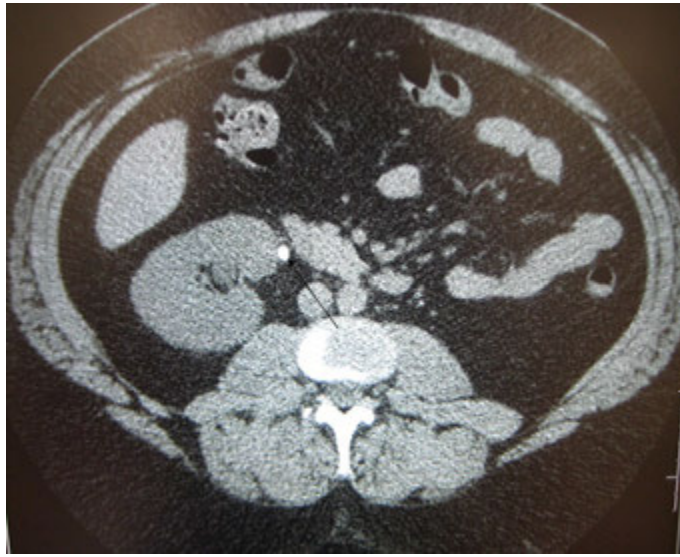


Figure 6.

CT scan of the right proximal ureter showing a stone (arrow) causing mild hydronephrosis in the kidney. [James Heilman, MD. CT abdomen without contrast showing right proximal ureteric stone causing mild obstruction and hydronephrosis [Internet]. Wikimedia Commons; [cited 2025 Sep 12]. Available from: <https://commons.wikimedia.org/w/index.php?curid=8602804>].

availability of scanners and personnel. It is no surprise that CT is also one of the most common imaging modalities used to evaluate patients with UI. There is a downside, however, as performing a CT examination involves the use of ionizing radiation, with a possibly increased lifetime cancer risk, especially notable when young patients are scanned, as well as the invasiveness of contrast administration and the possibility of contrast reaction and contrast-induced renal disease.

CT, in the currently most commonly used clinical setting, is a purely anatomical evaluation and may reveal any anatomical cause of UI. **Figure 6** demonstrates hydronephrosis and a kidney stone as seen in a CT scan.

The typical anatomical causes of obstructions include iatrogenic factors (such as the result of anti-incontinence surgery), mass lesions within the periurethral region, which may be benign or malignant, pelvic organ prolapse, and congenital urethral valves.

The primary sign would be anatomical disruption from one of the causes mentioned above, directly visible on imaging. On cross-sectional imaging such as CT or MRI, this disruption appears as a sharp termination of the urinary tract, often accompanied by dilation of the urinary tract just upstream of the termination due to urinary retention. Masses that cause external or internal compression are often visible. For example, an enlarged prostate is almost always well visualized, even on ultrasound, and is seen much more clearly on CT and MRI. A benign or malignant mass compressing the urinary system can also be visualized, best with CT using contrast or MRI. Special examinations such as CT IVP, traditional IVP, or VCUG (voiding cystourethrography) can visualize the internal structure of the urinary

tract, and blockage or obstruction appears as filling defects. Fluoroscopy examinations performed while voiding can also diagnose functional abnormalities of the urinary system.

Secondary signs would be chronic anatomical/physiological changes from urinary retention. For example, a thickened bladder wall with a full bladder (not to be confused with a partially empty/collapsed bladder) can be seen in chronic urinary retention. Iatrogenic objects, such as a chronic Foley or suprapubic catheter, may be visible to provide clues to a patient's status as someone suffering from chronic urinary obstruction. These secondary signs are well evaluated by CT.

Hydronephrosis is easily visualized on cross-sectional examination, showing up as dilation of the collecting system.

New hydronephrosis in an ill-appearing, febrile patient is highly concerning for sepsis and pyelonephritis until proven otherwise. This is a life-threatening finding and may require an immediate decompressive procedure, such as nephrostomy of the affected kidney.

Urinary fistulas are difficult to resolve via imaging due to the often-small size of fistulas. Ultrasound, CT, and MRI all have resolution thresholds. A common knowledge pearl for cross-sectional imaging would be that the appearance of gas in a typically gasless urinary bladder may suggest a fistula between the rectum or vagina in women. In practice, the usage of intravenous contrast or contrast administered via catheters can improve the detection rate of urinary leaks/fistulas by providing enhanced contrast resolution between extravasated urine and surrounding structures. Antegrade or retrograde cystography/cystourethrogram/pyelogram may reveal even fairly small leaks/fistulas in real-time images.

Urinary tract infection is a common indication for imaging, especially ultrasound and CT. Common findings include bladder wall thickening, inflammatory changes around the bladder, collecting system and/or kidney, as well as causes of infection such as an obstructing stone. Gas in the bladder is another sign of infection or fistula in a patient who has not recently undergone instrumentation in the bladder.

3.4 Magnetic resonance imaging

Magnetic resonance imaging has become an increasingly valuable tool in the radiologic evaluation of UI, a condition that profoundly impacts quality of life and often requires a multidisciplinary approach to diagnosis and management. Although history-taking, physical examination, and urodynamic testing remain central to the initial assessment, these methods do not always reveal the full spectrum of structural and functional abnormalities contributing to incontinence. MRI, with its superior soft tissue contrast and multiplanar imaging capabilities, fills this diagnostic gap by offering detailed visualization of the pelvic floor and its supporting structures without exposure to ionizing radiation.

In the context of UI, MRI is most often employed to assess both the static anatomy and the dynamic function of the pelvic floor. **Figure 7** demonstrates an example of the anatomical features visible for assessing complex cases of UI. Patients are typically imaged with a moderately filled bladder, as this allows the radiologist to better evaluate the relationship between the bladder neck and urethra

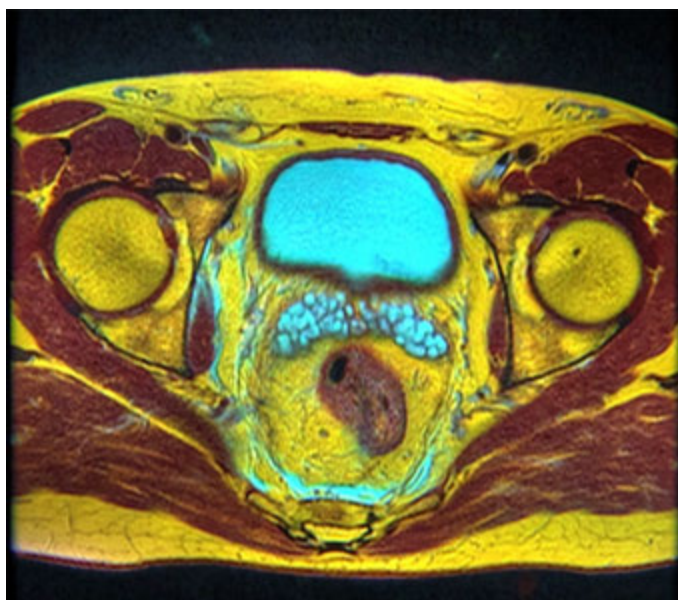


Figure 7.

Pelvic MRI highlighting bladder, rectum, muscles, and adipose tissue (Nevit Dilmen, CC BY-SA 3.0) “File: Pelvic MRI T1FSE T2FRFSE T2FSFRFSE 11.jpg” by Nevit Dilmen (talk) is licensed under [CC BY-SA 3.0](#).

during rest and strain. Standard T2-weighted sequences in the axial, sagittal, and coronal planes provide exquisite detail of the bladder, urethra, vagina, and surrounding musculature, while dynamic imaging during maneuvers such as Valsalva or coughing allows direct observation of urethral hypermobility, bladder neck descent, and organ prolapse. In some cases, rectal or vaginal contrast gel is introduced to further delineate pelvic compartments, and T1-weighted sequences may be added to investigate postsurgical changes such as scarring or hematomas [7].

One of the major strengths of MRI lies in its ability to demonstrate both the causes and the consequences of incontinence in a single study. The bladder and urethra can be examined for funneling, diverticula, or intrinsic sphincter deficiency, while the levator ani muscles and connective tissue supports are evaluated for avulsions, thinning, or defects. Unlike ultrasound or fluoroscopy, MRI offers a comprehensive view of all three compartments of the pelvis simultaneously, making it possible to diagnose coexisting conditions such as cystocele, uterine prolapse, or rectocele, which may influence management strategies. This holistic assessment is particularly important in women with complex or recurrent incontinence, where the interplay of multiple structural abnormalities often contributes to symptoms.

Clinically, MRI has several important applications. In patients whose symptoms persist despite conservative or surgical treatment, MRI can reveal occult pathology such as urethral diverticulum, fistulas, or subtle fascial defects that may not be apparent on other imaging modalities. **Figure 8** demonstrates an example of the “Donald Duck” appearance of the urinary bladder, a cause of lower urinary tract symptoms like UI. This image shows pelvic lipomatosis compressing the bladder,

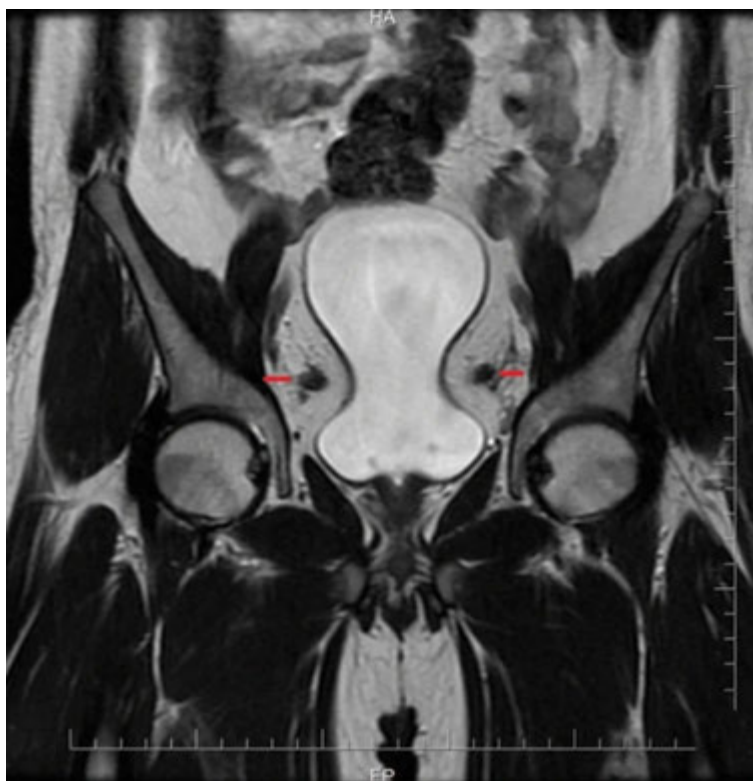


Figure 8.

Coronal MRI pelvis showing “Donald Duck” appearance with pelvic lipomatosis compressing the bladder. Sridharan Natarajan, Soumya Shivas Pattnaik, S. Bobby Viswaroop, and Ganesh Gopalakrishnan, in *Asian Journal of Urology* (2022), licensed under CC BY 4.0. Retrieved from Wikimedia Commons: [file:12,301 2022 271 Figure 2.html.Webp].

an example of anatomical or structural issues that could be identified using MRI. Surgeons frequently rely on MRI findings to plan interventions, since the detailed anatomic roadmap provided by the images helps to optimize the placement of slings, repair of fascial defects, or management of recurrent prolapse. Moreover, when surgery fails, MRI is often the modality of choice to identify complications such as mesh malposition, fibrosis, or unrecognized multicompartiment involvement. Beyond its clinical use, MRI also contributes to research efforts in pelvic biomechanics, with dynamic and even four-dimensional imaging increasingly employed to model the mechanics of continence and investigate novel therapies.

Dynamic pelvic floor MRI may be used to evaluate pelvic organ prolapse, given its excellent soft tissue contrast and real-time imaging capability. Different maneuvers may be incorporated to challenge a patient’s physiology; examples include rest, squeeze, Valsalva maneuver, and defecation/evacuation. Ultrasound gel is often instilled into the rectum for defecation sequences. Pelvic organ prolapse and its associated anatomical/physiological impact on continence can then be easily visualized, thanks to the superior soft tissue contrast of MRI.

Despite its advantages, MRI is not without limitations. It is more expensive and less widely available than ultrasound, requires specialized expertise for interpretation, and may be uncomfortable for patients with claustrophobia. The temporal resolution of MRI is lower than that of fluoroscopic methods, making it less effective for capturing very rapid events, such as transient leakage during a cough. Nevertheless, these limitations are outweighed in many complex cases by the unmatched soft tissue contrast and comprehensive evaluation it provides.

Looking toward the future, developments in three-dimensional and four-dimensional MRI, diffusion tensor imaging, and machine-learning-driven image analysis are expected to further refine the role of MRI in UI care. By combining advanced imaging data with urodynamic testing and clinical assessment, MRI has the potential to become an even more powerful tool in personalized treatment planning. At present, while it is not a first-line investigation for every patient with incontinence, MRI is indispensable in cases that are complex, refractory, or surgical in nature, and it continues to expand our understanding of the anatomy and physiology underlying this common and burdensome condition.

3.5 Fluoroscopy and videourodynamic studies

Fluoroscopy, particularly when integrated into videourodynamic studies, has long been considered a cornerstone of radiologic evaluation for patients with UI. Unlike static imaging modalities, fluoroscopy offers real-time visualization of the lower urinary tract during filling and voiding, making it uniquely suited to explore both functional and anatomical contributors to incontinence. While more recent imaging approaches, such as MRI, have gained attention for their ability to delineate pelvic anatomy in great detail, fluoroscopic urodynamics remains the gold standard for correlating urinary symptoms with bladder and urethral physiology under dynamic conditions [7].

The procedure begins with catheterization of the bladder, which is then filled with contrast medium while intravesical and sometimes intra-abdominal pressures are simultaneously measured. Continuous fluoroscopic imaging records the position and function of the bladder neck and urethra during filling, storage, coughing, straining, and voiding. This integration of pressure data with visual documentation provides a comprehensive assessment of detrusor activity, bladder compliance, urethral closure function, and the presence of vesicoureteral reflux or obstruction. In particular, videourodynamics has the distinct advantage of identifying the exact moment when leakage occurs, allowing the clinician to determine whether stress, urge, or mixed incontinence mechanisms are responsible.

For stress UI, fluoroscopy can reveal urethral hypermobility, bladder neck descent, and funneling during increased intra-abdominal pressure. In cases of urge incontinence, it may capture detrusor overactivity manifested as involuntary contractions during the filling phase, with or without associated leakage. The study is equally valuable in complex or recurrent presentations, where it can identify anatomical abnormalities such as diverticula, fistulas, or postsurgical complications such as obstruction following sling procedures. Importantly, videourodynamics can simultaneously highlight coexisting functional disturbances, such as poor bladder compliance, which might otherwise go undetected but have major implications for management and prognosis.

Clinically, the role of fluoroscopy and videourodynamics extends well beyond diagnosis. The results guide individualized treatment planning, distinguishing patients who would benefit most from surgical correction of stress incontinence from those whose primary issue is detrusor overactivity and who may respond better to pharmacological or behavioral interventions. In patients who have failed prior procedures, videourodynamics often clarifies whether recurrent symptoms stem from persistent urethral incompetence, postoperative obstruction, or a shift in pathophysiology over time. For surgeons, the real-time images and pressure tracings provide an invaluable framework for deciding on revision strategies, particularly in complex or iatrogenic cases [7].

Although fluoroscopy remains a powerful diagnostic tool, it is not without drawbacks. The use of ionizing radiation, albeit at relatively low doses, raises concerns, particularly in younger patients or those requiring repeated evaluations. The invasive nature of catheterization can be uncomfortable, and the artificial circumstances of bladder filling with contrast medium may not perfectly replicate natural voiding patterns. Additionally, the interpretation of videourodynamic studies requires significant expertise and experience, as subtle findings can be misinterpreted without careful correlation to symptoms and physical examination.

Nevertheless, videourodynamic fluoroscopy continues to hold an essential place in the diagnostic armamentarium for UI. Its strength lies in its ability to unite functional assessment with anatomic visualization, producing a dynamic record that no other modality can fully replicate. While newer imaging approaches, such as MRI, contribute complementary insights into pelvic structure and support, videourodynamics remains uniquely positioned to capture the physiology of continence and incontinence in action.

As technology advances, digital fluoroscopy with reduced radiation doses, improved image quality, and integration with computerized pressure-flow analysis is enhancing both patient safety and diagnostic accuracy. The continued evolution of these studies ensures that fluoroscopy will remain a vital and irreplaceable part of the comprehensive evaluation of patients with UI, bridging the gap between what can be seen anatomically and what can be measured physiologically.

4. Interventional radiology and downstream solutions for complex cases

Interventional radiology has many exciting, cutting-edge tools and techniques to treat UI. In general, IR techniques are used to correct the anatomical causes of UI. They can also enable artificial replacement structures for patients whose anatomical causes of UI become uncorrectable.

IR has an extensive array of techniques to “open what should not be closed and close what should not be open.” In application to the world of UI, IR may open narrowed soft tissue passages by balloon dilation, close fistulas/leaks by embolization, drain abscesses/infections involving the urinary system, and replace function with percutaneous nephrostomy and nephroureteral stents.

IR-guided dilation was first performed in 1964 by Dr. Dotter in a clogged leg artery, a moment thought to be the birthing cry of IR as a subspecialty. Subsequently, special balloons were developed to perform angioplasty/dilation. First, wires are guided across the area of narrowing; then, balloons are guided across the area of treatment over the wire. Next, balloons are inflated using a pressure pump to exert

radial pressure against the narrowing/lesion to stretch and destroy the narrowings. Some balloons may have small embedded blades to further cut the adhesion. Angioplasty in the urinary collecting system tends to be performed for benign strictures and is often combined with the placement of stents to provide a scaffolding over which the structure may heal [18]. Malignant strictures tend to be relentless and typically cannot be bridged with stents or balloon dilation over the long term, and those patients tend to require nephrostomy tubes.

IR has a long history of embolization, or blocking conduits within the body. Embolization may be performed in the urinary system to block urinary leakage. Due to limitations of the technique, IR embolization tends to be an all-or-nothing affair, with special challenges in the urinary system due to the presence of urine, a fluid that is nonclotting, unlike blood, and can be corrosive as well. Due to these limitations, IR embolization of urinary leaks tends to be reserved for difficult cases where other interventions have failed, and the entire ureter needs to be sacrificed to give patients a better function/quality-of-life outcome. It is drastic, as complete blockage/embolization of a ureter requires lifelong nephrostomy placement [19].

Drainage of an abscess is one of the most common procedures performed by IR. It can be performed under CT and/or ultrasound guidance. A needle is guided under CT or ultrasound into the target collection, then a wire is inserted, and a drainage catheter is placed over the wire into the collection. Alternatively, the collection/abscess may be aspirated to completion instead of leaving a drainage tube in [7].

Nephrostomy and nephroureteral stents can either act as temporary or permanent functional and anatomical replacements of the ureters, while suprapubic catheters essentially act as functional replacements of the urethra. Nephrostomy tubes are often placed for the immediate relief of “pus under pressure” in the setting of pyelonephritis as well. Typically, an interventional radiologist (IR) would use a combination of ultrasound and fluoroscopy to enter a calyx of the kidney with a needle. Next, a thin wire is placed into the needle, and through a series of exchanges with gradually enlarging instruments, this eventually results in the placement of a fairly large catheter into the renal collecting system.

Interventional radiology offers minimally invasive options to address structural or postsurgical contributors to UI that may not be amenable to conservative or surgical care alone. Techniques such as balloon dilation, embolization, abscess drainage, and nephrostomy or stent placement provide targeted solutions to relieve obstruction, seal urinary leaks, or bypass compromised anatomy. These procedures play an important adjunctive role in refractory cases, often improving patient comfort, preserving renal function, and avoiding more invasive surgery. **Table 2**

Procedure	Application in UI	Notes/limitations
Balloon dilation	Relieve benign strictures causing obstruction.	Often combined with nephroureteral or other urinary stents.
Embolization	Seal urinary leaks or fistulas.	Reserved for refractory/difficult cases.
Abscess drainage	Manage infectious complications contributing to UI.	CT/US guided.
Nephrostomy/nephroureteral stent placement	Bypass obstruction, preserve renal function.	Temporary or long-term solutions by recreating functional equivalents of urinary conduits.

Table 2.
Interventional radiology approaches.

summarizes the principal IR approaches, their clinical applications, and key limitations, providing a concise overview for integration into multidisciplinary continence management [18, 19].

5. Interdisciplinary collaboration

The effective management of UI necessitates a concerted effort from a diverse team of healthcare professionals. A truly patient-centered approach relies on seamless communication and collaboration between urologists, radiologists, interventional radiologists, and nurses. This interdisciplinary approach leverages the unique expertise of each specialist, resulting in optimized diagnostic strategies, tailored treatment plans, and improved patient outcomes. The cornerstone of this collaborative model is shared decision-making, where all team members contribute their perspectives to formulate the most appropriate course of action for each individual patient.

Urologists, specialists in the urinary system, play a pivotal role in diagnosing and treating UI. They conduct comprehensive examinations, order necessary diagnostic tests, and develop personalized treatment plans. Their expertise in evaluating bladder function, identifying underlying anatomical abnormalities, and selecting appropriate surgical interventions is crucial for complex cases. However, their contribution extends beyond direct patient interaction. They play a crucial role in guiding the interdisciplinary team, providing essential medical insight, and contributing to the overall strategic plan for the patient.

Radiologists, skilled in interpreting medical images, provide invaluable diagnostic information. They analyze imaging studies, such as ultrasound, CT scans, and MRI, to identify structural abnormalities contributing to UI, such as pelvic organ prolapse or bladder stones. Their detailed reports help urologists and interventional radiologists refine their diagnostic assessments and tailor their treatment plans accordingly. The precise information gained from radiologic imaging can be critical in determining the suitability of various therapeutic options and in pre- and postprocedural assessments. The radiologist's detailed description of the anatomy and the precise location of any relevant abnormalities are crucial to guiding the interventional radiologist during minimally invasive procedures.

Interventional radiologists bring a unique set of skills to the table. Their expertise in minimally invasive procedures allows for targeted treatment of UI, often avoiding the need for extensive surgery. Techniques such as bladder injections (e.g., for bulking agents) or embolization procedures for vascular malformations can significantly improve patient outcomes, with reduced recovery time and risk compared to open surgery. Their collaboration with urologists is particularly essential in complex cases requiring a combined surgical and IR approach. They provide a valuable alternative or adjunct to traditional surgical interventions, offering a range of less invasive treatment options. The close collaboration between the interventional radiologist and the urologist allows for a precise assessment of the patient's condition and the selection of the most appropriate procedure.

Nurses are at the forefront of patient care, playing a crucial role in UI management. Their consistent presence allows for ongoing monitoring of the patient's response to treatment, the identification of any potential complications, and the timely intervention necessary to maintain or improve the efficacy of the

prescribed management plan. This ongoing assessment is vital in ensuring patient comfort and adherence to the treatment plan. Their meticulous observation skills identify subtle changes, providing the opportunity for early intervention and preventing potentially serious complications.

Effective interdisciplinary collaboration relies on robust communication channels and regular team meetings. These meetings provide a platform for healthcare professionals to share their observations, discuss patient progress, and collaboratively adjust treatment plans as needed. The sharing of information and perspectives enhances overall management, facilitates effective decision-making, and ensures a cohesive approach to the patient's care. The sharing of data, including patient history, test results, imaging findings, and treatment responses, streamlines the management process and minimizes the risk of any discrepancies.

Successful models of interdisciplinary UI care often involve the creation of specialized UI clinics or multidisciplinary teams dedicated to the comprehensive management of this condition. These clinics bring together specialists from various disciplines, fostering collaboration and ensuring coordinated care. Within these clinics, efficient workflows and clear communication protocols are established, maximizing the effectiveness of the interdisciplinary approach. These clinics are designed to provide a comprehensive assessment and management plan for each patient, maximizing the utilization of the expertise of the specialists involved.

Despite the significant benefits of interdisciplinary collaboration, several challenges can hinder its effectiveness. Differing professional perspectives, scheduling conflicts, and communication barriers can sometimes impede seamless collaboration. However, effective strategies can mitigate these challenges. Implementing clear communication protocols, scheduling regular team meetings, and adopting shared electronic health records can facilitate smoother information exchange and reduce misunderstandings. Furthermore, establishing a culture of mutual respect and shared decision-making can foster a collaborative environment where all team members feel valued and empowered.

One example of synergistic effects in a complex UI case demonstrates the importance of interdisciplinary collaboration. Consider a patient with mixed incontinence, experiencing both stress and urge incontinence alongside significant pelvic organ prolapse. An urologist performs a comprehensive assessment, including urodynamic studies, which reveal the specific contribution of each type of incontinence to the patient's condition. A radiologist evaluates the pelvic MRI, identifying the extent of the prolapse and any anatomical abnormalities affecting bladder function. Based on this combined assessment, the interventional radiologist may perform a minimally invasive procedure to address the prolapse, such as a sacrocolpopexy, while the urologist focuses on managing the underlying bladder dysfunction with medication and behavioral therapies. Nurses provide ongoing support, education, and monitoring, ensuring the patient's compliance with the treatment plan and addressing any concerns or complications. This integrated approach improves patient outcomes significantly, exceeding what could be achieved through a solely urology-focused approach.

The effective management of UI requires a collaborative approach that leverages the diverse expertise of urologists, radiologists, interventional radiologists, and nurses. Shared decision-making, effective communication channels, and the implementation of shared electronic health records are essential for optimizing care. While challenges may exist, proactive strategies to overcome communication

barriers and foster a collaborative environment improve patient outcomes and enhance the quality of life for those affected by UI. The seamless integration of these specialties, guided by a patient-centered approach, produces superior outcomes, underscoring the critical importance of this interdisciplinary model. The development of specialized UI clinics further strengthens this collaborative effort, centralizing resources and expertise for improved efficiency and patient care. The proactive management of challenges and the establishment of clear protocols ensure the long-term success of interdisciplinary collaboration in UI management.

6. Future directions: Strengthening diagnostics and expanding adjunctive options

The future of UI care will be shaped not by a single modality but by better integration of complementary tools, particularly advanced imaging and interventional techniques, within a broader, patient-centered care continuum. Based on the direction of this chapter, a five-prong approach to better UI management is discussed below.

I. Advancing imaging to refine diagnosis

Imaging continues to gain ground in UI workup, particularly in identifying secondary causes such as BOO, hydronephrosis, or fistulas. Future research should aim to refine imaging protocols, improve diagnostic specificity, and develop clearer criteria for when advanced imaging adds value beyond standard clinical assessment.

II. Defining the role of IR in complex cases

IR is not a primary treatment for UI but can play a meaningful role in resolving underlying structural or postsurgical complications contributing to incontinence. Research should focus on where IR is most effective, such as managing fistulas, urinary leaks, or decompressing obstructed systems, and developing decision frameworks to guide timely referrals when conservative and surgical options fall short.

III. Supporting technology integration without replacing core therapies

Technologies such as AI-powered imaging analysis and robotic-assisted surgery offer potential benefits in complex or surgically challenging cases. These innovations are best viewed as extensions of existing pathways rather than replacements. Research should explore how such tools can enhance the accuracy, safety, and efficiency of care across specialties.

IV. Fostering cross-specialty collaboration and research

To build a more coordinated UI care model, collaboration between urology, radiology, IR, nursing, and physical therapy must be strengthened. Future work should prioritize multicenter studies, shared diagnostic pathways, and collaborative outcome tracking, especially in cases where UI is a secondary symptom of a more complex condition.

V. Enhancing clinical decision-making and referral processes

As diagnostics evolve, clinicians need clearer guidance on when to escalate UI

evaluation with imaging or refer for interventional procedures. Developing clinical algorithms that align with evidence-based thresholds can support timelier, appropriate care and avoid unnecessary delays in complex or refractory cases.

7. Conclusion(s)

Urinary incontinence is rarely, simply put, just the leakage of urine, and managing it effectively means recognizing when it is a primary condition or when it signals something deeper. While behavioral, pharmacologic, and surgical treatments remain the cornerstones of care, there are clear situations where imaging and, in select cases, IR can uncover or address the root causes of persistent symptoms.

Interventional radiology is an important tool within a broader multidisciplinary framework. Its value lies in identifying and resolving structural contributors to UI when standard care pathways are insufficient. Similarly, diagnostic radiology enhances the accuracy and completeness of assessments, helping clinicians make better-informed decisions.

The way forward is about integrating the right tools at the right time, with the right team. When radiologists, urologists, nurses, and other specialists collaborate seamlessly, patients benefit from a more complete evaluation and more precise, appropriate interventions. The future of UI care is multidisciplinary, layered, and responsive – one where traditional management remains central but is strengthened by diagnostic precision and targeted procedural support when complexity demands it.

In conclusion, effective management of UI requires recognizing when traditional approaches may fall short, particularly in complex or refractory cases. While behavioral, pharmacologic, and surgical treatments remain central, this chapter highlights the added value of diagnostic imaging and IR as supportive tools in identifying and addressing underlying structural contributors. Despite its high prevalence, UI remains widely undertreated and poorly understood, both by the public and healthcare professionals. This gap in knowledge contributes to delays in diagnosis and care. A multidisciplinary approach, bringing together urologists, radiologists, interventionalists, nurses, and allied health professionals, is essential to ensuring timely diagnosis, targeted interventions, and coordinated care. The future of UI management lies not in isolated advances but in the integration of specialties, where collaborative care models enhance outcomes and offer more precise, patient-centered solutions.

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Conflict of interest

No conflicts of interest to report.

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Section 3

Therapeutic Approaches
in Benign Prostatic
Hyperplasia and Female
Urinary Incontinence

Chapter 5

Urinary Incontinence Problems and Coping Strategies in Women

Nazife Akan and Behire Sançar

Abstract

Although urinary incontinence (UI) is not life-threatening, it is a common health problem that reduces women's quality of life. The International Continence Society (ICS) defines UI as the involuntary leakage of urine. Many women may experience UI at any time in their lives. The prevalence of UI in women varies between 5% and 70%. Women with UI mostly do not want to apply to a health institution because of embarrassment or perceiving the problem as a normal situation. There are different ways of treatment and rehabilitation that can improve the quality of life for people with UI problems. UI treatment and support options should be individualized and determined by a healthcare professional, depending on each individual's symptoms, age, general health, and underlying causes of incontinence. In the field of preventive health services, nurses and family physicians can help individuals in the early period through education and counseling.

Keywords: nursing, preventive health, treatment and rehabilitation, urinary incontinence, women's health

1. Introduction

Urinary incontinence (UI) is a symptom characterized by the involuntary loss of urine and loss of bladder control. The World Health Organization (WHO) and the International Continence Society (ICS) define UI as “an objectively demonstrable involuntary loss of urine that constitutes a social and hygienic problem” [1, 2]. Although not life-threatening, persistent micturition and irritation negatively affect the quality of life [3]. UI affects millions worldwide and is a multifaceted public health issue with physiological, psychological, social, and cultural dimensions. It is more prevalent in women due to biological processes such as pregnancy, childbirth, menopause, and hormonal changes [4–6]. Population-based studies report UI prevalence ranging from 5% to 70%, with most studies indicating 25–45% [7]. Its frequency increases with age, especially postmenopause, due to weakening pelvic floor muscles and impaired bladder control mechanisms [8, 9]. Despite its prevalence, help-seeking rates among women remain low. Liang et al. [10] found that only 28% of women with UI sought professional help [10]. Similarly, Li et al. [11] and Komeilifar et al. [12] reported that many women perceive UI as a natural part of aging and delay treatment [11, 12]. Shame, stigma, fear of surgery, and privacy concerns

are among the reasons for not seeking treatment [5, 13, 14]. Gencer et al. [15] highlighted the impact of UI on hygiene, social life, and sexual relationships [15]. Appropriate evaluation and treatment can significantly improve the quality of life [16].

2. Anatomical structures involved in continence

Urinary continence is maintained through the coordinated function of four key components of the lower urinary tract:

- Bladder and detrusor muscle
- Urethral sphincter mechanism
- Pelvic support structures
- Estrogen sensitivity in the female lower urinary tract

These structures are regulated by the autonomic and somatic nervous systems. Anatomical integrity, muscle tone, and neural coordination form the physiological barriers that prevent involuntary urine leakage (**Figure 1**) [17, 18].

2.1 Bladder and detrusor muscle

2.1.1 Anatomical structure and function of the bladder

The bladder temporarily stores urine and facilitates its voluntary release. This requires intact anatomy and functional neural control [20, 21]. The bladder consists

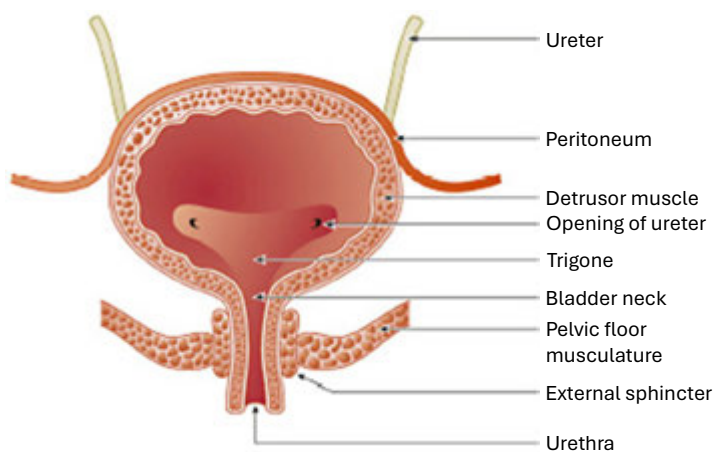


Figure 1.

Key anatomical components of the lower urinary tract and their roles in continence mechanisms. From: medivizor. 5 Facts About the Bladder [Internet]. 2017 Nov 25 [cited 2025 Sep 23]. Available from: <https://medivizor.com/blog/2017/11/25/5-facts-about-bladder/> [19].

of two main regions: the corpus and the trigone. The corpus is composed of multidirectional smooth muscle fibers called the detrusor, which relax during storage and contract during voiding [22, 23]. The inner surface is lined with transitional epithelium and contains rugae that allow expansion. Beneath lies the submucosa and the detrusor muscle, which is active in both storage and voiding phases [20]. The trigone, located between the ureteral orifices and bladder neck, funnels urine during voiding and prevents vesicoureteral reflux [17]. During filling, the detrusor remains relaxed, maintaining low pressure. Sympathetic innervation (T10–L2) via the hypogastric nerve activates β -adrenergic receptors to relax the detrusor and α -adrenergic receptors to increase tone in the bladder neck and trigone, supporting continence [17, 23]. When bladder fullness reaches a threshold, parasympathetic innervation (S2–S4) via the pelvic nerve contracts the detrusor and relaxes the sphincters, enabling voluntary voiding [3, 20]. The ureterovesical junction compresses the ureters during pressure elevation, preventing reflux [24].

2.1.2 Neural control mechanisms of the bladder

- **Autonomic nervous system**

- Sympathetic (T10–L2): increases tone in the bladder neck and trigone via α -receptors
- Parasympathetic (S2–S4): contracts the detrusor via the pelvic nerve during voiding

- **Somatic system**

- Pudendal nerve (S2–S4): innervates the external urethral sphincter for voluntary control

- **Central control**

- Frontal cortex: initiates voluntary voiding
- Pontine micturition center (PMC): coordinates bladder and sphincter
- Spinal cord: transmits afferent and efferent signals [17]

- **Viscero-somatic reflexes**

Afferent C and A-delta fibers activate mechanoreceptors during bladder filling, modulating somatic motoneuron excitability. Neurochemical mediators, such as substance P, glutamate, ATP, GABA, and glycine, regulate reflex intensity. NMDA receptor activation and peptides like CGRP and neuropeptide Y influence reflex duration and spread [25–27].

2.2 Urethral sphincter mechanism

The urethra extends from the bladder neck to the external meatus. Its segmental anatomy and neural control are critical for continence [28, 29]. In females, the

external sphincter is more complex, involving fibers that contribute to both urethral and vaginal constriction [30].

2.2.1 Internal sphincter – bladder neck and proximal urethra

Composed of smooth muscle fibers, the bladder neck functions as a passive closure zone. Sympathetic innervation (T11–L2) via the hypogastric nerve increases tone during filling, preventing leakage and reflux [23, 28].

2.2.2 External sphincter – midurethra

Surrounded by pelvic fascia and ligaments, this true anatomical sphincter contains both smooth and striated muscle. Voluntary contraction via the pudendal nerve (S2–S4) maintains active continence [17, 28].

2.2.3 Distal urethra

Located near the vaginal vestibule, it consists of striated muscle under voluntary control. Histologically, it contains stratified squamous epithelium, vascular submucosa, and mucosal glands that provide a sealing effect and microbial defense [18, 30].

2.2.4 Neurophysiological modulation and reflex contributions

Visceral afferents modulate somatic motoneuron excitability during bladder filling. Excitatory neurotransmitters (glutamate, substance P, ATP) and inhibitory ones (GABA, glycine) regulate reflex strength. NMDA receptors, CGRP, and neuropeptide Y modulate sphincter responses [27]. **Figures 2 and 3** illustrate the anatomical and functional neuromotor control mechanisms of the lower urinary tract [31].

2.3 Pelvic support structures

Urinary continence is maintained not only by bladder and urethral function but also by the anatomical integrity and neuromuscular coordination of pelvic support structures. The pelvic floor is a complex support system composed of passive (connective tissue, fascia) and active (muscle groups) components. These structures ensure the proper positioning of pelvic organs, maintain urethral closure pressure, and enable coordinated relaxation during voiding [32, 33].

Key anatomical components and their roles in urethral control include:

- Levator ani muscle group: comprising the pubococcygeus, iliococcygeus, and puborectalis muscles; striated in nature and providing superior support to pelvic organs.
- Endopelvic fascia: a connective tissue network surrounding the bladder, urethra, and vagina; it ensures urethral stability.

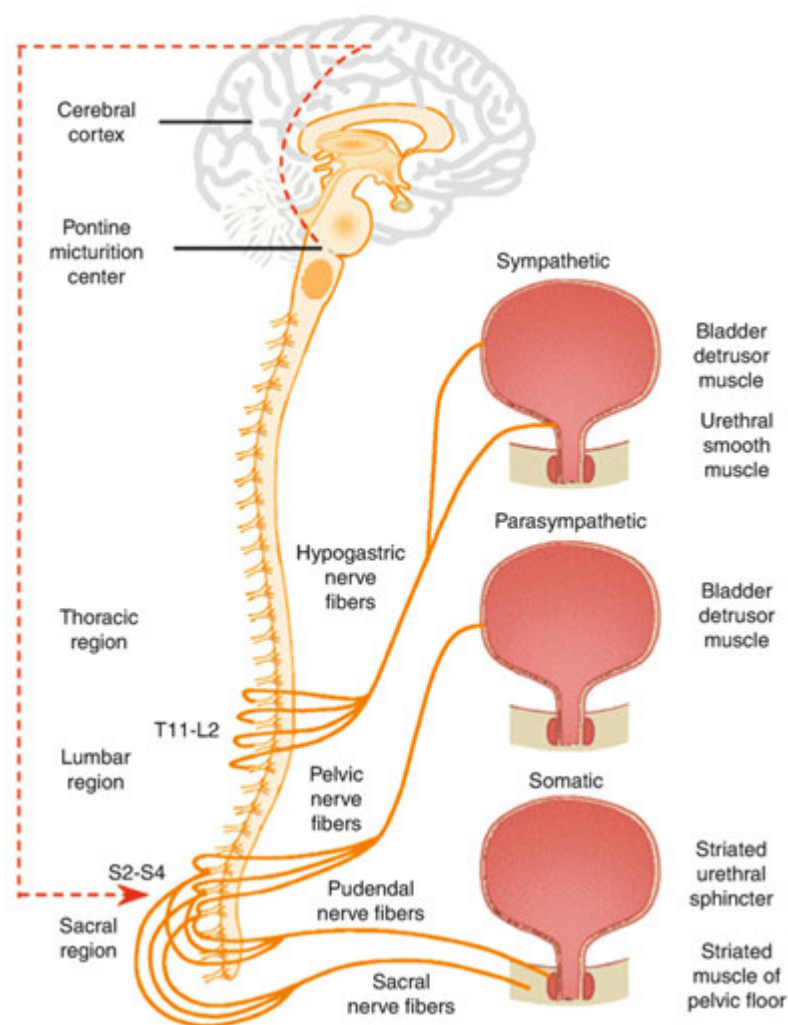


Figure 2.
 Peripheral nervous control of the lower urinary tract: functional innervation of the bladder and urethra, showing the roles of parasympathetic, sympathetic, and somatic pathways, along with receptor-level interactions [31].

- Pubourethral ligaments: they anchor the midurethra to the pubic bone, providing fixation.
- Urogenital diaphragm: includes the external urethral sphincter and perineal muscles; essential for maintaining active continence.

These structures form an anatomical support framework around the urethra, preserving the position of the bladder neck and urethra. During stress conditions, such as standing, coughing, or exercise, this support acts as a barrier against urine leakage [32].

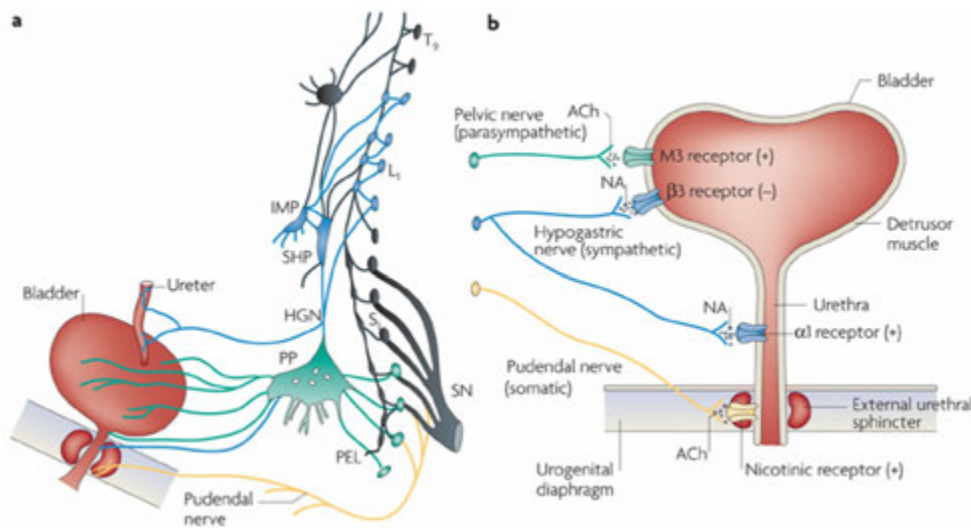


Figure 3. Central and peripheral neural control of bladder function. The diagram illustrates the anatomical pathways (a) and functional innervation; (b) of the bladder and urethra, including parasympathetic (pelvic nerve), sympathetic (hypogastric nerve), and somatic (pudendal nerve) inputs, along with their associated receptors and neurotransmitters [31].

The physiological impact of pelvic support structures depends on muscle fiber type and neural control:

- Type I (slow-twitch) fibers: provide sustained tone; predominant in the levator ani and support pelvic viscera passively.
- Type II (fast-twitch) fibers: respond rapidly to pressure changes; increase urethral closure pressure during coughing or sneezing.

These muscles are under somatic control via the pudendal nerve (S2–S4). Voluntary contractions activate the external sphincter and maintain active continence. Pelvic floor contractions also support sphincteric structures around the urethra, enhancing closure pressure [17, 28].

Weakness or injury to pelvic support structures may lead to stress urinary incontinence (SUI), especially in women. Childbirth, aging, obesity, and pelvic surgeries can impair these mechanisms. Pelvic floor muscle training (PFMT) forms the basis of conservative treatment, aiming to improve urethral support and sphincter function [34]. Home-based PFMT, supported by mobile applications, improves treatment adherence and reduces symptoms, contributing to continence both physiologically and behaviorally [35].

2.4 Estrogen sensitivity in the female lower urinary tract

The female lower urinary tract is highly sensitive to estrogen. Structures such as the urethra, bladder trigone, vaginal epithelium, and pelvic floor muscles are rich in estrogen receptors [8, 36]. These receptors are located in epithelial cells, submucosal

vasculature, connective tissue, and pelvic support structures. Estrogen's effects on these tissues play a critical role in maintaining continence mechanisms.

2.4.1 Effects on urethral tissue

Estrogen enhances urethral closure pressure and mucosal sealing. During the climacteric period, declining estrogen levels lead to mucosal atrophy and thinning. This weakens the mucosal barrier, triggering symptoms such as nocturia, dysuria, and frequency. Pelvic muscle atrophy and reduced collagen contribute to the increased prevalence of UI and pelvic organ prolapse [37, 38]. Estrogen supports hydration, vascularization, and regeneration of periurethral tissues, strengthening the barrier against infection and irritation [36].

2.4.2 Effects on the bladder and detrusor

Postmenopausal estrogen deficiency is associated with collagen accumulation in the bladder wall and reduced detrusor contractility, contributing to urge incontinence [39]. Histological studies show increased expression of mechanosensitive proteins Piezo1 and TRPV4 under estrogen-deficient conditions, which may trigger frequent urination and nocturia. Estrogen replacement therapy can normalize these protein levels and improve bladder function.

2.4.3 Effects on pelvic floor muscles

Estrogen deficiency may weaken pelvic floor muscles, increasing the risk of prolapse and stress incontinence. Although estrogen receptors are present in these muscles, direct evidence of structural weakening remains limited [40, 41]. Estrogen influences muscle tone and elasticity, enhancing peripheral reflex responses [42]. Recent neurobiological studies show that ESR1⁺ neurons in the Barrington nucleus coordinate bladder contraction and external sphincter relaxation via pudendal and pelvic nerves, contributing to the neurological basis of continence [43].

3. Continence mechanism: Pressure balance and neurological control

The continence mechanism is maintained by the pressure difference between the bladder and urethral closure pressure. When this balance is disrupted:

- Stress incontinence occurs due to decreased urethral closure pressure.
- Urge incontinence results from a sudden increase in bladder pressure, leading to involuntary voiding. In both cases, insufficiency in neurological control and anatomical support mechanisms leads to continence failure.

3.1 Urethral continence mechanism

Urethral continence is a multilayered system that prevents involuntary urine leakage. It functions through the coordination of passive anatomical structures and active neuromuscular control. The internal urethral sphincter, composed of smooth

muscle, provides autonomic control, while the external sphincter, composed of striated muscle, offers voluntary control via somatic nerves. Pelvic floor muscles and the endopelvic fascia support the urethra and enhance closure pressure [44]. In women, the fullness of vascular submucosal structures and mucosal thickness, influenced by estrogen levels, strengthen the sealing effect. Afferent and efferent signals originating from sacral nerves regulate sphincter reflex activity and maintain continence. Dysfunction in this system may lead to urethral insufficiency, especially in stress and mixed-type incontinence cases [45].

3.2 Normal voiding process: Pressure balance and neural coordination

Continence is preserved through bladder–urethra pressure balance and the neurological mechanisms that regulate it. This system operates under the coordination of autonomic (sympathetic and parasympathetic) and somatic nerve networks governed by the central nervous system (CNS) [17, 18], (**Table 1**). The lower urinary tract consists of the bladder, bladder neck, and urethra. The bladder stores urine and periodically empties through the outlet channel formed by the bladder neck and urethral sphincter complex. Coordination among these structures is achieved through neural connections between the frontal cortex, PMC, sacral spinal segments, and peripheral ganglia.

3.2.1 Storage phase: Pressure regulation and sphincter activation

During the storage phase, the bladder expands without a significant increase in internal pressure due to its high compliance. This is achieved by the suppression of the parasympathetic nervous system (S2–S4, pelvic nerve) and the inhibition of detrusor muscle activity [46]. Simultaneously, the bladder neck and urethra contribute to urine retention by generating active closure pressure:

- Sympathetic system (T11–L2, hypogastric nerve) stimulates α -adrenergic receptors to increase smooth muscle tone.

Level	Structures/ centers	Nerves	Function	Neurotransmitters/ modulators
Supraspinal	Cerebral cortex, PAG, PMC	–	Voluntary control of micturition, reflex inhibition	Glutamate, GABA
Spinal	T11–L2 (sympa- thetic), S2–S4 (parasympathetic/ somatic)	Hypogastric, pelvic, pudendal	Storage and voiding reflexes, sphincter coordination	Substance P, CGRP, ATP, NMDA, Glycine
Peripheral	Bladder, urethra, sphincter	Pelvic, pudendal	Muscle contraction/relaxation, mucosal sealing, voluntary sphincter control	Acetylcholine, nora- drenaline, estriol, estrogen
Hormonal modulation	ESR1 ⁺ neurons, estrogen receptors	–	Hormonal influence on neurore- gulation, sphincter relaxation, mucosal integrity	Estriol, estrogen, neuropeptide Y

Table 1.
Neurophysiological regulation of the bladder and urethra.

- Urethral mucosa and submucosal vasculature provide a “cushion effect” for sealing.
- External urethral sphincter, activated voluntarily via the somatic system (S2–S4, pudendal nerve), adds support to continence [17].

This physiological balance maintains low bladder pressure and high urethral closure pressure. The resulting pressure gradient prevents involuntary urine leakage.

3.2.2 Voiding phase: Neurological coordination and muscle synchronization

The voiding process is governed by three main regions of the CNS:

- Frontal cortex initiates the voluntary decision to void.
- PMC ensures synergy between the bladder and the urethra.
- The sacral spinal cord transmits autonomic and somatic signals to peripheral nerves [17, 18].

During voiding, the parasympathetic system is activated; the pelvic nerve contracts the detrusor muscle, increasing bladder pressure. Simultaneously, the internal and external sphincters relax, allowing urine to be expelled.

4. Pathophysiology of UI

UI arises from disruptions in the complex interactions between neural, muscular, and connective tissue components of the bladder and urethra. Normal urinary control depends on the coordinated function of the CNS, detrusor muscle, urethral sphincter, and pelvic floor muscles. Dysfunction in any part of this system may result in involuntary urine loss [1, 44].

4.1 Weakness of pelvic floor muscles

Pelvic floor muscles are essential for supporting lower urinary tract organs such as the bladder and urethra. Weakness in these muscles plays a critical role in the development of SUI. Factors such as childbirth, aging, obesity, and hormonal changes reduce pelvic floor tone and decrease urethral closure pressure. Pelvic floor dysfunction leads to urethral hypermobility, compromising bladder neck support and increasing the risk of leakage [47–49].

4.2 Urethral sphincter insufficiency

The urethral sphincter serves as the primary barrier preventing urine from exiting the bladder. Structural or functional impairments, especially urethral hypermobility or intrinsic sphincter deficiency, reduce closure capacity and lead to stress incontinence [50]. Postmenopausal estrogen deficiency may further weaken sphincter function [51].

4.3 Detrusor overactivity

Urge incontinence is primarily caused by involuntary contractions of the detrusor muscle. This results in a sudden urge to void and urine leakage, even when bladder volume is insufficient. Detrusor overactivity may be due to neurological disorders, bladder irritation, or idiopathic causes [1, 52]. Clinically, this mechanism corresponds to overactive bladder syndrome.

4.4 Neurological mechanisms

Urinary control depends on the coordination of the brain, spinal cord, and peripheral nervous system. Neurological disorders, such as multiple sclerosis (MS), spinal cord injuries, and Parkinson's disease (PD), can impair bladder sensation and sphincter control, leading to various types of incontinence [44]. In such cases, disrupted neural transmission results in a loss of coordination between the bladder and sphincter.

4.5 Hormonal influences

Estrogen enhances urethral mucosal thickness and vascularization, supporting sphincter function. Postmenopausal estrogen decline leads to mucosal thinning and atrophy, increasing the risk of urinary leakage [51]. Local estrogen therapies target this mechanism and may alleviate symptoms.

4.6 Anatomical changes

Pelvic organ prolapse alters the anatomical positioning of the bladder and urethra, complicating urinary control. Cystocele, in particular, changes urethral angles and contributes to stress incontinence [48, 50]. These anatomical changes may be associated with surgical history or connective tissue weakness. When combined with cultural stigma, they may delay treatment-seeking behavior [52].

5. Classification of UI in women

5.1 Stress incontinence

SUI occurs due to the failure of the urethral closure mechanism during increased intraabdominal pressure. It is associated with weakened pelvic support structures, urethral sphincter insufficiency, and neuromuscular control disorders [4].

5.1.1 Weakening of pelvic support structures

Structures such as the levator ani muscles, endopelvic fascia, and pubourethral ligaments provide support to the bladder neck and urethra. Weakening of these structures due to childbirth, aging, obesity, or hormonal changes leads to bladder neck hypermobility. When the bladder neck cannot move upward with the urethra during increased intraabdominal pressure, urine leakage occurs [53].

5.1.2 Urethral sphincter insufficiency

Reduced contractile capacity of the internal and external urethral sphincters lowers urethral closure pressure. With aging, striated muscle fibers in the external sphincter may undergo atrophy and neurogenic degeneration [54]. This can result in SUI even when pelvic support structures remain intact.

5.1.3 Neuromuscular control disorders

Pudendal nerve injury may occur due to childbirth trauma or surgical interventions. Disruption of nerve transmission reduces the reflex contraction capacity of pelvic floor muscles. Postpartum pudendal neuropathy is a significant factor in the development of SUI [29, 55].

5.1.4 Hormonal influences

Estrogen deficiency leads to mucosal atrophy and reduced vascularization in the urethra. This decreases urethral closure pressure and increases the risk of incontinence. Local estrogen therapy in postmenopausal women can improve mucosal thickness and alleviate symptoms [56].

5.2 Urge incontinence

Urge UI is characterized by a sudden, intense, and uncontrollable urge to urinate, often accompanied by involuntary leakage. Other symptoms include increased urinary frequency and nocturia. This condition is also known as overactive bladder (OAB) and is commonly associated with detrusor overactivity. Several pathological mechanisms contribute to urge incontinence:

5.2.1 Neurogenic lower urinary tract dysfunction based on lesion level

Lesions in the central or peripheral nervous system, particularly spinal cord injuries, can lead to neurogenic lower urinary tract dysfunction (NLUTD). Depending on the lesion level—suprapontine, pontine, suprasacral, or infrasacral – bladder and sphincter coordination may be impaired, resulting in detrusor overactivity or acontractility [57, 58], (**Table 2**). Suprapontine lesions (e.g., stroke, PD) result in detrusor overactivity with preserved sphincter synergy [59]. Pontine lesions disrupt the micturition center, causing detrusor–sphincter dyssynergia and bladder outlet obstruction.

- Suprasacral lesions: detrusor overactivity with dyssynergia, leading to urgency and incomplete voiding [60].
- Infrasacral lesions: hypotonic or atonic detrusor, flaccid sphincter, and retention or overflow incontinence.
- Pudendal nerve damage: may cause stress incontinence due to external sphincter insufficiency.

Lesion level	Anatomical location	Bladder activity	Sphincter function	Clinical outcome
Suprapontine	Cerebral cortex, basal ganglia	Detrusor overactivity	Coordinated sphincter	Urge urinary incontinence
Pontine	Pontine micturition center	Detrusor overactivity	Detrusor–sphincter dyssynergia	Bladder outlet obstruction
Suprasacral	Spinal cord (T10–L2)	Detrusor overactivity	Detrusor–sphincter dyssynergia	Urge urinary incontinence
Infrasacral	Sacral cord (S2–S4), cauda equina, pelvic nerves	Hypotonic or atonic detrusor	Weak or flaccid sphincter	Retention, overflow incontinence
Pudendal nerve	Peripheral nerve	Normal detrusor	External sphincter insufficiency	Stress urinary incontinence

Table 2.
Neurogenic bladder dysfunction based on lesion level.

5.2.2 Bladder irritation and molecular mechanisms

Irritative conditions such as urinary tract infections, bladder stones, interstitial cystitis, and tumors stimulate afferent nerve endings in the bladder wall, lowering the threshold for the micturition reflex and triggering involuntary detrusor contractions [39, 61, 62]. Inflammatory responses involve increased release of cytokines like IL-6, IL-8, and TNF- α from mast cells, macrophages, and epithelial cells [63, 64]. Uropathogens such as *E. coli* and *Enterococcus faecalis* form intracellular bacterial communities (IBCs), enhancing epithelial inflammation and neuronal sensitivity.

5.2.3 Medications and stimulants

Diuretics, antidepressants, muscle relaxants, caffeine, and alcohol can stimulate bladder activity. Caffeine lowers the micturition threshold by enhancing afferent signaling, while alcohol suppresses antidiuretic hormone release, increasing the bladder filling rate [65–67].

5.2.4 Aging and hormonal changes

Aging reduces bladder capacity and compliance, while increasing spontaneous detrusor contractions. Postmenopausal estrogen deficiency leads to mucosal thinning and heightened afferent sensitivity [39]. Epidemiological studies identify age, race, obesity, smoking, pregnancy, menopause, constipation, vaginal delivery, caffeine intake, carbonated beverages, hysterectomy, and pelvic surgery as risk factors [65, 67].

5.2.5 Psychological factors

Emotional states, such as anxiety and stress, activate the sympathetic nervous system, triggering bladder contractions. Limbic system responses interact with the PMC, lowering the threshold for the micturition reflex [68].

5.2.6 Overactive bladder mechanisms without detrusor overactivity

OAB symptoms may occur even in the absence of detrusor overactivity, often due to urothelial dysfunction and hypersensitive afferent signaling [63, 64]. The urothelium acts as a sensor-organ, releasing neurotransmitters like ATP and acetylcholine in response to bladder filling. Dysfunctional urothelium increases afferent sensitivity, triggering urgency without detrusor contractions [69–73].

5.3 Mixed urinary incontinence

Mixed urinary incontinence (MUI) is a clinical condition characterized by the coexistence of stress and urge incontinence. Patients experience involuntary urine leakage triggered both by physical exertion and sudden, intense urgency. MUI typically results from simultaneous pelvic floor muscle weakness and bladder hyperactivity. Recent studies suggest that its pathophysiology involves not only mechanical factors but also complex neuromuscular and hormonal interactions [44]. In postmenopausal women, estrogen deficiency reduces urethral closure pressure and increases bladder irritability, contributing to mixed symptoms. Additional risk factors, such as obesity, multiparity, and prior pelvic surgeries, weaken pelvic support structures, exacerbating the stress component, while neurogenic changes in the bladder wall trigger the urge component [74]. Clinically, patients report urine leakage during physical activities (e.g., coughing, laughing, and exercise) as well as during sudden urgency episodes. This dual presentation complicates diagnosis and treatment, as targeting a single mechanism is often insufficient. Urodynamic evaluation plays a key role in diagnosing MUI by revealing both detrusor overactivity and urethral insufficiency [75]. Treatment should be individualized. First-line approaches include lifestyle modifications, PFMT, and bladder training. Pharmacological therapies, such as antimuscarinics or β_3 -agonists, target the urge component, while pelvic floor rehabilitation addresses the stress component. In refractory cases, advanced options like botulinum toxin injections or sacral nerve stimulation may be considered [45]. Recent studies emphasize the importance of a multidisciplinary approach in managing MUI. Collaboration among physiotherapy, urology, and gynecology improves long-term outcomes [74].

5.4 Overflow incontinence

Overflow incontinence is a lower urinary tract disorder characterized by low-pressure, continuous urine leakage due to bladder overdistension. It is typically associated with inadequate bladder emptying and occurs when bladder capacity is exceeded. Pathophysiologically, it involves reduced detrusor contractility, impaired bladder sensation, and outlet obstruction [39]. Common causes include diabetic neuropathy, spinal cord lesions, PD, and MS. Anatomical obstructions such as benign prostatic hyperplasia, pelvic tumors, or prior pelvic surgeries may also contribute. Inability to sense or empty the bladder leads to overstretching of the bladder wall and reduced muscle tone, resulting in continuous leakage [29]. Clinically, patients present with symptoms such as frequent urination, nocturia, weak stream, intermittent voiding, and incomplete emptying. Suprapubic fullness may be noted on physical exam. Postvoid residual (PVR) measurement is critical for diagnosis; elevated PVR indicates inadequate emptying. Urodynamic studies

confirm detrusor weakness or outlet obstruction [76]. Treatment depends on the underlying cause. Neurogenic cases may require intermittent catheterization, antimuscarinics, or β 3-agonists; anatomical obstructions may necessitate surgical intervention. Supportive strategies include bladder training, fluid management, and pelvic floor rehabilitation [77].

5.5 Functional incontinence

Functional incontinence occurs when individuals are unable to reach the toilet in time due to physical, cognitive, or environmental barriers, despite normal urinary tract function. It is common among elderly individuals with conditions such as dementia, stroke, PD, or mobility limitations [78]. Management requires a multidisciplinary approach, including environmental modifications (e.g., improved toilet access), assistive devices, caregiver support, and cognitive rehabilitation. In nursing homes, prevalence ranges from 20% to 30% [79].

5.6 Transient incontinence

Transient incontinence is a reversible form of urinary leakage caused by temporary factors such as diuretic use, acute urinary infections, constipation, excessive fluid intake, delirium, or certain medications [80]. In hospitalized elderly patients, overlooking transient causes may delay diagnosis and treatment. The “DIAPPERS” acronym (Delirium, Infection, Atrophic urethritis/vaginitis, Pharmaceuticals, Psychological, Excess urine output, Restricted mobility, Stool impaction) serves as a clinical guide. Treatment focuses on resolving the underlying cause – for example, treating infections, adjusting medications, or managing fluid intake [77].

6. Risk factors for UI

6.1 Aging and UI

Aging contributes to UI through gradual changes in the physiological, hormonal, and neurological components of the urinary system. Degeneration of elastic fibers and reduced vascular support may lead to stress incontinence, especially during increased abdominal pressure. Additionally, weakened neurological control mechanisms delay the processing of bladder fullness signals, facilitating the development of urge incontinence [81]. Stress incontinence is most common among middle-aged women (25.3%), while urge incontinence is more prevalent in women over 75 (24.2%) [6]. The prevalence of UI increases gradually with age, peaking between ages 50–59, plateauing in the 70s, and rising again in the 80s. Some studies suggest that stress incontinence is more common in women under 60, while urge incontinence predominates in older women [82]. Postmenopausal estrogen decline leads to thinning of the urethral mucosa and loss of elasticity in pelvic connective tissues. These hormonal and neurological changes increase the likelihood of coexisting stress and urge incontinence in older women [83]. Age-related weakening of neurological control disrupts coordination between the frontal lobe and PMC, delaying behavioral responses to bladder signals and increasing involuntary voiding

reflexes [81]. Additional age-specific factors, such as cognitive decline, mobility limitations, and polypharmacy, indirectly affect continence. In particular, the prevalence of UI is significantly higher among individuals with dementia [84].

6.2 Genetic and sociocultural factors

UI is a multidimensional condition shaped not only by anatomical and behavioral factors but also by genetic predisposition and sociocultural diversity. Recent genome-wide association studies (GWAS) have identified single nucleotide polymorphisms (SNPs) associated with stress and mixed-type UI. For example, a SNP near chromosome 17 is linked to stress UI, while another near the Myoferlin (MYOF) gene is associated with MUI. These variants may influence both risk and treatment response [85]. Polymorphisms in SMAD3 and SMAD7 genes (e.g., rs12901499 and rs12953717) have been associated with connective tissue integrity and cell signaling, linking genetic susceptibility to pelvic organ prolapse and lower urinary tract symptoms (LUTS) [86]. Twin and family studies also highlight hereditary influences, showing clustering of UI in certain individuals. This genetic predisposition becomes more meaningful when considered alongside geographic and ethnic differences. Meta-analyses among African women report a UI prevalence of approximately 24% (95% CI: 17–33), with stress UI at 35%, MUI at 31%, and urge UI at 28%. Prevalence is higher in North Africa (41%) than in Sub-Saharan Africa (19%). Studies using ICS definitions report higher prevalence rates (38% vs. 21%) [87]. A US-based study found that White women have a higher prevalence of UI compared to Black and Hispanic women. Stress UI is more common among White women, while urge UI is more frequent among Black women. These differences are attributed to pelvic floor anatomy, birth practices, hormonal profiles, and healthcare-seeking behaviors [88].

6.3 Obesity

Obesity is recognized as both a significant and modifiable risk factor for UI in women. Increased intraabdominal pressure, mechanical load on the pelvic floor, and metabolic alterations negatively affect continence mechanisms [89, 90]. Abdominal obesity exerts continuous pressure on the bladder and urethra, triggering SUI. This load weakens pelvic floor muscles, promotes urethral hypermobility, and impairs sphincter function [89]. Visceral fat-induced oxidative stress disrupts collagen metabolism in the pelvic cavity, reducing connective tissue resilience [91]. Elevated body mass index (BMI) increases intravesical pressure beyond urethral closure pressure, raising the risk of both stress and urge incontinence [92]. Metabolic effects of obesity also compromise continence. Adipokines such as leptin and resistin, along with proinflammatory cytokines like TNF- α and IL-6, reduce pelvic connective tissue elasticity and urethral closure pressure [90]. Hyperglycemia associated with insulin resistance and metabolic syndrome impairs peripheral nerve function, increasing the risk of detrusor overactivity and sphincter dysfunction [93]. Clinical studies show that obesity contributes not only to stress but also to mixed-type UI. Botlero et al. [6] reported a strong association between obesity and MUI [6]. Meta-analyses indicate that obese women have nearly twice the risk of UI compared to those with normal BMI [89, 94]. Weight loss is an effective strategy for reducing obesity-related UI symptoms. Doumouchtsis et al. [95] found that SUI prevalence

dropped from 61% to 11% after weight loss [95]. Subak et al. [96] observed significant reductions in UI episodes following a six-month behavioral intervention [96]. Postbariatric surgery evaluations revealed a decrease in UI prevalence from 66.7% to 37.0% at 12 months, with a strong correlation between BMI reduction and continence improvement [93, 97]. Obesity also poses obstetric risks, increasing the likelihood of gestational diabetes and macrosomia, which can damage the pelvic floor and lead to urethral sphincter insufficiency [98]. These findings highlight that obesity affects UI risk through mechanical, metabolic, and neurological pathways.

6.4 Effects of menopause on UI

Postmenopausal estrogen decline plays a critical role in the development of stress, urge, and MUI in women. High-affinity estrogen receptors in the urethra, pubococcygeal muscle, and bladder trigone explain the hormonal impact on the lower urinary tract [53]. During hypoestrogenic states, collagen degradation, reduced urethral vascularity, and mucosal thinning lower urethral closure pressure, increasing the risk of stress incontinence [38, 99]. Simultaneously, decreased pelvic muscle tone and elasticity weaken peripheral reflex responses, contributing to urge symptoms [43]. Estrogen deficiency also disrupts vaginal flora, weakens epithelial barriers, and reduces antimicrobial defense, facilitating bacterial colonization. These changes increase bladder irritability and trigger urgency and leakage episodes [100, 101]. Robinson and Cardozo [36] reported that 50% of postmenopausal women experience stress UI, and 20% experience urge UI [36]. Estrogen deficiency lowers sensory thresholds in trigonal and urethral receptors, impairing Valsalva leak point pressure and increasing leakage risk. It also weakens connective tissue, contributing to sphincter dysfunction – a key mechanism in stress UI [101, 102]. Recent studies show that estrogen receptor expression (ER α and ER β) in pelvic floor muscles supports structural integrity and reflex capacity. Estrogen deficiency is linked to muscle atrophy and reduced proprioceptive sensitivity. Estradiol has been shown to facilitate external sphincter relaxation via ESR1⁺ neurons in the PMC, enhancing peripheral reflex activity through the pudendal nerve [43]. These hormonal changes contribute to urgency symptoms by increasing afferent nerve excitability and urogenital atrophy. Estrogen decline plays a key role in the pathophysiology of OAB and urge incontinence [77, 103] and helps explain the neurophysiological basis of stress and MUI in postmenopausal women.

6.5 Obstetric and gynecological factors

Pregnancy and childbirth induce lasting changes in pelvic floor physiology, increasing the risk of UI in women. Even without delivery, pregnancy-related uterine enlargement, hormonal shifts, and elevated intraabdominal pressure cause stretching and relaxation of pelvic support tissues. Compared to nulliparous women, those who have experienced pregnancy show a higher risk of UI, especially when the first pregnancy occurs at an advanced maternal age [104]. Transperineal ultrasound studies reveal structural changes during pregnancy, including bladder neck descent, hiatal widening, and altered urethral angles. These changes predispose women to stress and urge incontinence, even in the absence of delivery [105], highlighting the need to assess pregnancy's impact on pelvic health independently of birth. Childbirth itself is a major risk factor for UI. Vaginal delivery exposes pelvic

floor muscles, connective tissues, and the pudendal nerve to mechanical and neurological trauma. These injuries weaken urethral support and impair bladder control [106]. Compared to women who have not given birth, those who have are more likely to experience stress UI. This is due to direct damage to pelvic musculature and connective attachments, as well as nerve injury from trauma or overstretching [6, 53]. Multiparity – having multiple deliveries – is directly linked to pelvic floor dysfunction. Women with three or more vaginal births show higher rates of levator ani muscle damage and hiatal enlargement, increasing the risk of stress UI and pelvic organ prolapse [107]. Mode of delivery is also a key factor: vaginal births exert more trauma on the pelvic floor than cesarean sections, especially when assisted with vacuum or forceps, which can severely damage the urethral sphincter and bladder support [108]. Even after a first birth, significant pelvic floor changes are observed. Studies report that 26% of primiparous women develop stress UI and 52% develop anterior vaginal wall prolapse [106]. These findings demonstrate that obstetric factors affect pelvic floor physiology both anatomically and functionally, and that birth-related trauma has long-term implications for continence mechanisms. Hysterectomy has been inconsistently associated with UI risk. However, current evidence does not support avoiding hysterectomy for continence preservation, nor does it endorse supracervical hysterectomy as a preventive measure [53]. These findings suggest that pregnancy, as well as childbirth itself, has significant effects on pelvic floor health. These effects may be particularly pronounced in women experiencing their first pregnancy at an older age.

6.6 Neurological factors

Neurological disorders affecting the CNS – including the cerebrum, brainstem, and spinal cord – can impair the supraspinal centers responsible for urinary control, leading to neurogenic incontinence. These conditions may result in involuntary detrusor contractions (detrusor overactivity), loss of sphincter coordination, and uncontrolled triggering of the micturition reflex. Disorders such as stroke, PD, MS, dementia, spinal cord injury, and multiple system atrophy can disrupt lower urinary tract control and cause both urinary and fecal incontinence [109]. In suprapontine lesions, loss of cortical control leads to detrusor overactivity and urge incontinence. Autonomic dysfunction seen in PD, multiple system atrophy, and certain types of dementia impairs both storage and voiding functions. In cognitive disorders such as dementia, behavioral incontinence is common due to cognitive decline and motor limitations [110].

6.6.1 Multiple sclerosis and incontinence

MS is a chronic autoimmune disease characterized by demyelination within the CNS. This process disrupts signal transmission in the cerebral cortex, brainstem, and spinal cord, leading to neurogenic bladder dysfunction. The most common urinary symptoms in MS include detrusor overactivity, detrusor-sphincter dyssynergia, and voiding difficulty [111]. Demyelination in supraspinal centers, such as the PMC and periaqueductal gray (PAG), causes involuntary detrusor contractions. Lesions in the sacral spinal cord impair external sphincter coordination, resulting in voiding dyssynergia. Disruption of afferent signaling can reduce or delay bladder sensation, contributing to overflow incontinence [112]. Clinical studies show that 50–80% of

MS patients experience urinary symptoms, which increase with disease progression [111, 112].

6.6.2 Parkinson's disease and incontinence

PD is a progressive neurodegenerative disorder marked by the degeneration of dopamine-producing neurons. This affects not only motor function but also autonomic regulation, leading to bladder dysfunction. The most common urinary symptom in PD is detrusor overactivity, typically presenting as urge incontinence [113].

Pathophysiological mechanisms include:

- Basal ganglia dysfunction, reducing inhibitory control over the PMC
- Frontal cortex impairment disrupting voluntary voiding
- Autonomic dysfunction delaying bladder fullness perception
- Detrusor overactivity, triggering urgency at low volumes

Studies report that 40–70% of PD patients experience urinary symptoms such as nocturia, urgency, voiding difficulty, and increased PVR volume. These symptoms worsen with disease progression and significantly impact quality of life. Dopamine deficiency is directly linked to bladder dysfunction, and dopamine agonists may alleviate symptoms in some patients [114].

6.6.3 Diabetic neuropathy and incontinence

Diabetic neuropathy, caused by prolonged hyperglycemia, leads to peripheral and autonomic nerve damage. This impairs bladder innervation and results in neurogenic bladder dysfunction. Common symptoms include voiding difficulty, increased residual volume, weak detrusor contractility, and overflow incontinence [115]. Studies show that 25–50% of diabetic patients experience bladder dysfunction, often with an insidious onset. Recent research links diabetic bladder dysfunction to reduced peripheral nerve conduction velocity and altered neurotransmitter activity in the bladder wall.

6.6.4 Cognitive impairment and incontinence

Age-related changes in the frontal lobe, basal ganglia, and executive networks weaken neurocognitive control of micturition. These changes play a key role in the development of urge incontinence. Cognitive dysfunction in CNS disorders affects behavioral and executive functions of supraspinal centers, leading to neurocognitive incontinence. Dysfunction in the frontal lobe, anterior cingulate gyrus, and basal ganglia impairs inhibition and timing of voiding behavior [116]. Executive dysfunction delays appropriate behavioral responses to bladder fullness. Attention and inhibition deficits cause loss of control between urgency and reflex voiding. Frontal lobe impairment reduces voluntary control and environmental judgment, increasing involuntary leakage episodes [81, 117]. These mechanisms are especially

pronounced in dementia, where distinguishing between functional and neurological incontinence is critical for clinical management [81, 118].

6.6.5 Spinal cord injury and incontinence

Urinary storage and voiding are regulated by integrated CNS and peripheral pathways. During storage, A δ fibers activate sympathetic pathways via the pelvic nerve, contracting the bladder neck and urethra while relaxing the detrusor. The Onuf nucleus supports external sphincter contraction via the pudendal nerve. During voiding, A δ signals stimulate the PAG and PMC, which activate parasympathetic pathways and inhibit sympathetic and somatic inputs, enabling coordinated voiding [111]. Spinal cord injuries at T12–L1 disrupt bladder innervation, motor control, and sexual function. These injuries impair spinal reflex arcs and supraspinal control, causing detrusor-sphincter dyssynergia. This leads to high intravesical pressure, increased residual urine, and recurrent infections [39, 119]. Clinical studies show that bladder sensation during filling provides diagnostic clues about reflex activity and supraspinal control. Loss of supraspinal control contributes to dyssynergia and incontinence [120].

6.7 Pharmacological risks

Polypharmacy is a significant risk factor for UI, especially in older adults. Some medications directly affect bladder muscle activity, while others impair voiding control via neurological pathways. Drug-induced incontinence is typically secondary, and understanding the underlying pharmacological mechanisms is critical for clinical management [84, 121]. Diuretics increase urine production, accelerating bladder filling and potentially causing urge incontinence. Anticholinergic drugs reduce bladder contractility, leading to voiding difficulty and overflow incontinence. Markland et al. [122] demonstrated that anticholinergic use significantly increases UI risk in older women [122].

Alpha-blockers reduce urethral tone, causing sphincter relaxation and triggering stress incontinence. Sedatives and benzodiazepines impair cognitive awareness and motor coordination, contributing to functional incontinence. Ouslander and Schnelle [123] reported a direct link between sedative use and incontinence in nursing home residents [123]. Antidepressants, particularly SSRIs, alter neurotransmitter levels and may cause sphincter relaxation, contributing to mixed-type incontinence. Resnick and Yalla [124] suggested that detrusor and sphincter dysfunction in older adults may be drug-induced [124]. These effects vary depending on age, comorbidities, and environmental factors. In older adults, detailed medication history, review of new-onset UI symptoms, and multidisciplinary pharmacological optimization are recommended [125].

6.8 Other risk factors

6.8.1 Mobility limitations and environmental factors

Mobility impairment is a key determinant of UI in older adults. Even when bladder fullness is perceived, physical barriers or environmental challenges may delay toilet access and increase involuntary leakage episodes [123]. Chen et al. [76]

found higher UI prevalence among women who were married or partnered, physically inactive, and had chronic illnesses or cognitive impairments [76]. Mobility limitations are especially pronounced in conditions like osteoarthritis, poststroke hemiparesis, or balance disorders. These extend toilet access time and delay behavioral responses, leading to functional incontinence [121]. Environmental factors include toilet distance, door thresholds, slippery floors, poor nighttime lighting, and lack of assistive devices. These increase nocturnal incontinence risk. Staffing shortages or delayed assistance in care settings also contribute to UI frequency [84]. Clinical strategies include mobility support, environmental adjustments, and ensuring toilet accessibility tailored to physical capacity.

6.8.2 Psychosocial factors and UI

UI is not solely a physiological disorder – it is shaped by interactions with the psychosocial environment. In older adults, stress, depression, social isolation, and care settings can influence bladder control through behavioral and neurocognitive pathways [84]. Depression is associated with reduced frontal lobe activity and executive dysfunction, delaying behavioral responses to bladder fullness and increasing involuntary voiding [117]. Motivation deficits may also impair toilet-seeking behavior. Stress activates the sympathetic nervous system, increasing bladder irritability; stress may trigger detrusor overactivity and urge incontinence [118]. Social isolation and inadequate care environments reduce the ability to express toilet needs. In dementia patients, delayed or misunderstood help requests increase functional incontinence [123].

6.8.3 Tobacco and alcohol use

Tobacco use: smoking is a risk factor for SUI at both physiological and behavioral levels. Chronic coughing weakens pelvic floor muscles, increases intraabdominal pressure, and strains the sphincter mechanism [53]. Nicotine directly stimulates bladder muscles, causing detrusor overactivity. The vascular effects of tobacco reduce oxygenation in bladder and urethral tissues, impair regeneration, and worsen age-related incontinence [117].

Alcohol use: alcohol acts as a CNS depressant, weakening inhibition mechanisms and delaying behavioral responses to bladder fullness, contributing to functional incontinence [118]. Its diuretic effect increases urine production, raising nocturnal incontinence risk. Long-term use impairs neurocognitive function and bladder control [84].

6.8.4 Fluid intake and dietary habits

Excessive fluid intake, especially in short intervals, accelerates bladder filling and may trigger urge incontinence. Conversely, fluid restriction can concentrate urine and increase bladder irritability [121]. Caffeinated beverages and acidic foods irritate the bladder mucosa, promoting detrusor overactivity [84]. Dietary habits also have indirect effects. Constipation increases pelvic floor pressure, triggering stress incontinence. Low-fiber diets and inadequate hydration exacerbate this condition.

6.8.5 Sleep disorders and nocturnal incontinence

Sleep disorders common in older adults – such as insomnia, frequent nighttime awakenings, and difficulty falling asleep – impair nocturnal bladder control. Neurological conditions or nocturnal polyuria may trigger nighttime incontinence [118]. Poor toilet access at night and environmental barriers increase the risk of functional incontinence. Sleep disruption also weakens neurocognitive networks involved in bladder control [117].

6.8.6 Cardiovascular diseases and UI

Cardiovascular diseases contribute to UI through both direct physiological and treatment-related mechanisms. In older adults, heart failure, hypertension, and vascular disorders affect bladder function. Diuretics used in treatment increase urine production, accelerating bladder filling and raising the risk of urge and nocturnal incontinence [121]. Reduced pelvic blood flow in chronic cardiovascular disease impairs tissue oxygenation and increases bladder irritability [84]. Combined with diabetes, autonomic dysfunction may disrupt bladder innervation, leading to voiding difficulty and urge incontinence [117]. The prevalence of incontinence rises in older adults with cardiovascular comorbidities due to medication side effects and reduced physical capacity [118].

7. Diagnostic and evaluation process

Diagnosing UI requires a multidisciplinary approach to determine the type, severity, and underlying pathophysiological mechanisms. The process begins with a detailed patient history, including the onset of symptoms, triggering factors, frequency of leakage, and impact on quality of life [126].

7.1 Clinical evaluation

Physical examination is essential for assessing pelvic organ prolapse, vaginal atrophy, perineal sensitivity, and pelvic floor muscle strength. Stress incontinence can be observed using cough tests and the Valsalva maneuver. Neurological examination is also necessary to rule out functional and neurogenic causes [75].

7.2 Symptom questionnaires, diaries, and quality-of-life tools

A three to seven-day bladder diary helps objectively assess voiding frequency, leakage episodes, and fluid intake. Validated tools, such as the International Consultation on Incontinence Questionnaire (ICIQ), are used to measure symptom severity and impact on quality of life [77]. Instruments like the King's Health Questionnaire and ICIQ-LUTSqol allow objective evaluation of how incontinence affects daily life. These tools are also valuable for monitoring changes before and after treatment. The impact of UI on quality of

life must not be overlooked during treatment. A holistic approach should consider not only physical but also psychological and social needs.

7.3 Laboratory and urine tests

Urinalysis and culture are essential to rule out urinary tract infections, especially in urge incontinence. Blood glucose, creatinine, and electrolyte levels help evaluate systemic causes, such as diabetic neuropathy or renal dysfunction.

7.4 Postvoid residual (PVR) measurement

Ultrasound-based PVR measurement assesses bladder emptying efficiency and plays a critical role in diagnosing overflow incontinence. A residual volume above 100 mL indicates inadequate bladder emptying [79].

7.5 Urodynamic testing

Urodynamic studies objectively evaluate bladder filling and voiding phases. Conditions such as detrusor overactivity, urethral insufficiency, and bladder outlet obstruction can be differentiated. In mixed incontinence, the presence of both stress and urge components can be confirmed [126].

7.6 Standard imaging techniques

Pelvic ultrasound is used to assess bladder wall thickness, bladder neck position, and anatomical relationships of pelvic organs. Transperineal ultrasound provides noninvasive visualization of pelvic floor dysfunctions [127].

7.7 Advanced imaging and functional diagnostic methods

Cystography evaluates bladder capacity, vesicoureteral reflux, and bladder wall morphology. In spinal cord lesions, findings such as contrast extension into the posterior urethra and pseudodiverticulum formation aid in diagnosis [128]. Video-urodynamic testing combines pressure-flow data with real-time imaging to simultaneously assess structural and functional abnormalities such as detrusor-sphincter dyssynergia, diverticula, and reflux. It is considered the gold standard for diagnosing neurogenic bladder [129, 130]. Dynamic MRI offers high-resolution anatomical imaging of pelvic floor and bladder function. It is a noninvasive method, particularly useful in complex neurogenic cases, as a complement to conventional urodynamic tests [128].

8. Treatment options

The treatment of UI in women is planned based on the type and severity of incontinence, its impact on quality of life, and individual preferences. Treatment options range from conservative methods to surgical interventions. Conservative treatment options are shown in **Table 3**.

Behavioural and lifestyle changes	Regulation of fluid intake Reducing caffeine and alcohol consumption Bladder training Weight control
Pelvic floor muscle training	Kegel exercises

Table 3.
Conservative treatment options.

8.1 Behavioral and lifestyle modifications

The first-line management of incontinence generally involves lifestyle modifications. Regulating fluid intake, reducing caffeine and alcohol consumption, and establishing regular voiding habits are important behavioral interventions. Weight management should also be considered, as obesity increases pressure on the pelvic floor and may exacerbate stress incontinence [131].

8.2 Pelvic floor muscle training (kegel exercises)

Strengthening the pelvic floor muscles is particularly effective in the treatment of SUI. When performed regularly and with proper technique, these exercises can result in significant symptom improvement. PFMT is the most commonly recommended conservative treatment for women, as it is safe, effective, and improves quality of life [132]. Systematic reviews recommend conservative treatments, particularly PFMT, as first-line therapy for UI [133]. First introduced in 1948 by Arnold Kegel, these exercises aim to strengthen the pelvic floor muscles, enabling rapid and forceful contractions. This contraction pushes the urethra toward the pubic symphysis and compresses it. Training may also be supported by biofeedback or electrical stimulation under the supervision of a physiotherapist.

8.3 Pharmacological treatment

Pharmacological treatments for SUI in women include adrenergic receptor agonists, which increase urethral closure pressure and stimulate smooth muscle contraction; β -adrenergic receptor antagonists, which enhance norepinephrine activity at α -receptors to increase urethral outlet pressure; β -adrenergic receptor agonists, which improve striated sphincter contractility; and tricyclic antidepressants (TCAs), which reduce bladder contractility and exert systemic anticholinergic effects. Agents with anticholinergic effects suppress detrusor contractions and increase bladder capacity by decreasing compression during the filling phase of the bladder [134]. Modern anticholinergic drugs used for OAB have fewer side effects, and further studies may reduce the incidence of side effects even more [135]. In addition to serotonin-norepinephrine reuptake inhibitors, which increase urine storage by relaxing the bladder and raising pressure in the urethra, these inhibitors also play a role in reducing urge-type incontinence by suppressing overactivity of the detrusor muscle. Antimuscarinics (anticholinergics), which are the most commonly used medications for active bladder, and mixed-acting agents that block the entry of calcium into the bladder smooth muscle and act as antimuscular agents, are among the

pharmacological treatment methods used for UI in women. Estrogen replacement therapy, aimed at increasing urethral closure pressure, raising bladder sensation thresholds, and enhancing epithelial and α -adrenergic receptor density and sensitivity, is also among the therapeutic options [136, 137]. Topical estrogens can strengthen the urethral mucosa and support the management of stress incontinence in postmenopausal women. Pharmacological treatment should be planned according to side effects and the patient's overall health status.

8.3.1 Treatment of wet overactive bladder and urge UI

Pharmacological treatment for patients with wet OAB and urge UI primarily targets detrusor overactivity. Treatment options for this purpose may include:

- Antimuscarinics
- Beta-3 adrenergic receptor agonists
- Onabotulinum toxin A
- Sacral neuromodulation (SNM)
- Transcutaneous electrical nerve stimulation (TENS)

Antimuscarinics provide significant improvements in symptoms of urge incontinence, urgency, frequency, and nocturia. These drugs reduce involuntary contractions and increase bladder capacity by blocking acetylcholine binding to M3 muscarinic receptors in the detrusor muscle [138]. Compared to older agents, such as oxybutynin, newer antimuscarinics, such as solifenacin and darifenacin, are more selective and have fewer CNS side effects [139].

Beta-3 adrenergic receptor agonists (e.g., mirabegron and vibegron) offer an alternative or complementary treatment option. These agents promote bladder relaxation during the storage phase, increasing bladder capacity and reducing urgency episodes [140].

In carefully selected and adequately counseled patients who are resistant to oral pharmacotherapy, intravesical injection of Onabotulinum toxin A (Botox) may be the treatment of choice. This neurotoxin blocks the release of acetylcholine at the neuromuscular junction, causing temporary paralysis of the detrusor muscle and can significantly reduce episodes of urgency and UI [141]. However, patients should be informed about possible side effects, such as urinary retention and the need for intermittent catheterization.

Among nonpharmacological interventions, SNM and TENS offer additional treatment options for refractory cases. SNM modulates the neural pathways involved in bladder control through electrical stimulation of the sacral nerves and produces effective results in reducing urination frequency with urge UI [142]. TENS, a less invasive method, can improve symptoms by changing afferent signals and increasing inhibitory control on the detrusor muscle [143]. These advanced treatment options should be evaluated based on patient preference, comorbidities, and response to initial treatment. A multidisciplinary approach may be necessary for optimal outcomes in women with wet OAB and urge UI.

8.4 Supportive devices

- Vaginal pessary: a vaginal pessary is a device made of plastic or silicone that is inserted into the vagina to hold a prolapsed uterus or vaginal wall in place. It can reduce incontinence by increasing anatomical support in women with pelvic organ prolapse [144].
- Barrier devices: urethral tampons or incontinence pads can be used to help manage the symptoms caused by UI in daily life, such as wetness, discomfort, wet laundry, and external visibility. These products are used to provide temporary continence (in special cases, during sports, etc.) or in cases of need. It is important to replace these tools when they become wet [144].

8.5 Surgical treatment

In cases where conservative methods fail to provide sufficient relief, surgical intervention is considered. Currently, over 100 surgical techniques have been described for the management of SUI, with short-term success rates ranging from 73% to 96%, depending on the procedure. The choice of surgical approach depends on the type of incontinence, the presence and degree of pelvic organ prolapse, urethral scarring, age, weight, menopausal status, and the surgeon's preference. A comprehensive preoperative evaluation and patient counseling are essential. Surgical techniques include:

- Augmentation cystoplasty: also known as enterocystoplasty, this procedure increases bladder capacity. This technique may be indicated in patients with detrusor overactivity that has not responded to treatment options such as conservative therapy, sacral nerve stimulation, botulinum toxin injection, and myomectomy [145]. Postoperative monitoring of fluid and electrolyte balance is crucial.
- Detrusor myomectomy (DM): DM can be performed in patients with refractory or untreatable OAB, aimed at creating a large-capacity, low-pressure urinary reservoir [146].
- Retropubic suspension procedures: these involve laparoscopic suspension of the vaginal wall surrounding the midurethra and bladder neck to a retropubic position. Common techniques include Marshall-Marchetti-Krantz, Burch colposuspension, and paravaginal defect repair. Such procedures are indicated in women with urodynamic SUI and a hypermobile proximal urethra-bladder neck [147].
- Pubovaginal sling procedures: the goal of these procedures is to increase urethral resistance during stress, ensure adequate closure at rest, and allow spontaneous voiding [148]. It has been reported that this method can be applied as the primary surgical method in all SUI cases [149].

8.6 Alternative and complementary approaches

Methods such as acupuncture, biofeedback, and bladder training may support symptom control in some patients. These approaches are usually applied in addition to traditional treatments [144, 150]. The management of UI in women requires a multidisciplinary approach, with gynecologists, urologists, physiotherapists, and nurses collaborating to develop the most appropriate treatment plan for each patient.

9. Impact on quality of life

UI in women is not merely a physical health issue but also a complex condition with psychosocial dimensions. Urinary leakage can negatively affect daily activities, social relationships, emotional well-being, and overall quality of life.

9.1 Psychological effects

9.1.1 Anxiety and depression

Persistent fear of urinary leakage may lead to avoidance of social situations and isolation. UI, while a physical health problem, also significantly impacts the emotional and social aspects of a woman's life [151]. Women with UI often experience dermatological problems such as perineal irritation and infections due to impaired hygiene. Additionally, concerns about persistent odor and feeling unclean can lead to social isolation, embarrassment, reduced self-esteem, irritability, anger, and depression [152–154]. These issues contribute to a reduced quality of life in elderly women [155]. A study found that patients with SUI and MUI had significantly higher use of anxiolytics, antidepressants, TCAs, and anticholinergics compared to a control group [156].

9.1.2 Loss of self-confidence

UI negatively affects quality of life, leading to social isolation, depression, and decreased self-confidence [157]. Women with UI have lower self-esteem, higher anxiety levels, and are more prone to social withdrawal compared to those without UI [158].

9.1.3 Shame and stigmatization

Misunderstanding of incontinence in society may cause individuals to conceal their condition and avoid seeking help. Most women with UI eventually seek medical and social support, but many endure symptoms for at least two years due to hesitation [159, 160]. Social stigma can alter an individual's self-perception and behavior, leading them to conform to societal expectations [161]. Women with UI often isolate themselves socially in an effort to normalize urinary function [158]. Fear of stigmatization is a complex psychosocial factor that negatively affects life satisfaction [162].

9.2 Effects on social life

9.2.1 Social withdrawal

Women may avoid social activities due to the risk of urinary leakage. Perceived stigma in women with UI leads to social withdrawal and behavioral avoidance. Consequently, patients may receive less social support, show reluctance to accept their condition, and either delay or interrupt treatment [163, 164].

9.2.2 Challenges in work life

Episodes of urinary leakage during long meetings, travel, or physical activities can adversely affect job performance and motivation.

9.2.3 Sexual dysfunction

Fear of urinary leakage may lead to reduced sexual desire and avoidance of sexual activity. Female sexual dysfunction (FSD) is closely associated with LUTS [165]. In a study of 4,052 women, advanced age, stress incontinence, urge incontinence, mixed incontinence, diabetes, and cardiovascular comorbidities were identified as independent risk factors for FSD [166].

9.3 Physical discomfort

9.3.1 Skin irritation and infection risk

Persistent moisture in the genital area may lead to dermatological issues and infections. Although not life-threatening, ongoing wetness and irritation can cause distress and emotional problems, including depression [131].

9.3.2 Sleep disturbances

Nocturia (nighttime urination) can reduce sleep quality, adversely affecting overall health. In a study, it was reported that as women's incontinence quality of life worsened, sleep duration shortened, sleep disturbance increased, and sleep medication use also increased [167].

9.4 Economic burden

Costs associated with incontinence pads, medications, treatments, and hygiene products create an economic burden for both individuals and healthcare systems. UI affects the psychological, physical, social, and economic well-being of patients and their families [168]. The management of SUI is expensive for healthcare systems and imposes a significant financial burden on patients, with approximately 70% of expenditures attributed to routine care costs, including pads, diapers, laundry, and dry cleaning [169, 170]. Factors contributing to increased costs include the rising prevalence of urinary leakage, demand for improved quality of life, better recognition of the condition, increased use of surgical treatment compared to nonsurgical interventions, and improved access to healthcare [171]. Productivity loss

and difficulties in accessing treatment further reduce quality of life, particularly among low-income individuals. Studies have demonstrated a correlation between UI and increased healthcare utilization and costs [156].

10. Prevention and health education

The prevention and management of UI in women are achievable through raising awareness and reducing risk factors. Health education plays both a preventive and supportive role by raising public awareness and enhancing the quality of life.

10.1 Reducing risk factors

Risk factors for UI in women include pregnancy, vaginal delivery, age, and genetic predisposition. Additional contributing factors may include obesity, smoking, and constipation [156, 172, 173].

10.1.1 Vaginal delivery

Twelve years postdelivery, the prevalence of SUI is 55% among women with only vaginal deliveries, compared to 40% among those with only cesarean deliveries. These findings suggest a causal relationship between vaginal delivery trauma and SUI [172].

10.1.2 Weight management

It has been reported that obesity increases the pressure on the pelvic floor and is among the risk factors for UI [174]. Healthy nutrition and regular physical activity are essential for effective weight control.

10.1.3 Smoking

One of the risk factors that is effective in the development of UI is smoking [53, 117]. Chronic cough caused by smoking can trigger stress-type incontinence. Smoking cessation programs should be supported.

10.1.4 Prevention of constipation

Constipation is one of the risk factors that play a role in the development of UI. In a study, women with chronic constipation were found to have a higher level of acceptance of UI as a health problem [175]. Chronic constipation may damage the pelvic floor muscles. Constipation prevention measures, such as a fiber-rich diet and adequate fluid intake, should therefore be encouraged.

10.2 Control of chronic diseases

Keeping chronic diseases such as diabetes and hypertension under control is important for the prevention of UI. Diabetes has been reported as a significant predictor for the development of UI [176]. Another study reported higher prevalence

rates of diabetes and hypertension in individuals with OAB compared to those without OAB [177].

10.2.1 Bladder training

Excessively frequent or infrequent urination habits may impair bladder functions. Therefore, bladder training should be handled in two groups: decreasing and increasing the frequency of voiding.

1. Reducing the frequency of voiding: it is a technique performed to gradually increase the existing bladder capacity [144]. Bladder training is recommended as a first-line treatment for urge or mixed-type incontinence [178].
2. Increasing the frequency of voiding: in women with low voiding frequency, overfilling of the bladder carries a risk of incontinence. In this case, increasing the frequency of voiding may be useful. However, it should be noted that increasing the frequency of voiding may lead to overactive detrusor contractions by reducing bladder capacity [144].

10.2.2 Avoid heavy lifting

Activities that strain the pelvic floor muscles, such as heavy lifting, sneezing, coughing, and laughing, cause SUI by leading to involuntary leakage of urine from the external urethral orifice when abdominal pressure increases [179]. Avoiding heavy lifting may be useful in the prevention of SUI.

10.3 Protecting pelvic floor health

10.3.1 Pelvic floor muscle exercises

Strengthening the pelvic floor muscles after childbirth can reduce the risk of future incontinence. Pelvic floor muscle exercises (PFMEs) during pregnancy may reduce the risk of pelvic floor dysfunctions during late pregnancy and up to six months postpartum, and are recommended as an evidence-based practice for all pregnant women by international guidelines [180]. One study reported that 41% of women were aware of PFMEs prior to pregnancy, 30% practiced them, and 50% received information about PFMEs during antenatal visits [181]. In a study conducted in Australia, only 11% of pregnant women were found to practice PFMEs [182]. In their review, Bø and Nygaard [183] noted that women who specifically trained their pelvic floor muscles during pregnancy had a lower likelihood of experiencing childbirth-related complications [183].

10.4 Health education programs

Preventive strategies and health education are fundamental in managing UI at both individual and societal levels. Raising awareness among women contributes to symptom reduction and the preservation of quality of life.

10.4.1 Community-based education

Women should be informed about incontinence through seminars, brochures, and media campaigns. In a study conducted in Egypt on 292 women attending outpatient gynecology clinics in three public hospitals, significant improvements were observed in UI frequency and volume after participation in a Kegel exercise training program [184]. The same study also reported a statistically significant increase in perceived quality-of-life scores after the program [185].

10.4.2 Primary health care services

PFMEs applied during pregnancy can reduce the risk of pelvic floor disorders during late pregnancy and up to six months postpartum, and are recommended by international guidelines for all pregnant women [174]. Primary healthcare professionals, such as family physicians, nurses, and midwives, have various opportunities to provide education about PFMEs and support women in preventing pelvic floor dysfunctions [186]. As mentioned earlier, Daly et al. [181] found that 41% of women were aware of PFMEs prior to pregnancy, 30% practiced them, and 50% received information during pregnancy [181]. However, in a study conducted in Australia, only 11% of pregnant women practiced PFMEs [182, 187].

10.5 Support groups and counseling

Professionals providing psychosocial support can assist women in coping with the emotional challenges associated with UI. Studies have shown that awareness of PFMEs varies across populations and that women most often obtain this information from nurses or midwives [187]. Nursing counseling can provide personalized guidance and improve adherence to treatment.

10.6 Digital health applications

Mobile apps and online platforms facilitate access to pelvic floor exercises, bladder diaries, and educational materials. Mobile health applications have been used in various conditions requiring behavior change, such as morbid obesity, to improve and enhance treatment quality [188]. The development and use of mobile applications for patients with pelvic floor disorders is an increasingly popular and innovative intervention worldwide. It is believed that such technologies facilitate behavioral awareness and promote change through digital tools [189]. These technologies enable individuals to manage their own health more effectively.

11. Conclusion

Urinary incontinence is a health problem that negatively affects the physical and psychosocial quality of life of women of almost all ages. Knowing the causes, mechanisms, medical and supportive approaches to urinary incontinence will increase the motivation of healthcare professionals working in women's health.

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Urinary tract dysfunction is composed of various pathological disorders that can lead to severe complications and can strongly reduce patients' quality of life, even when symptoms are still mild. Early diagnosis and treatment prevent severe damage to the upper and lower urinary tracts and allow symptom improvement with conservative, noninvasive therapeutic approaches. Rigorous application of international guidelines in diagnostic and therapeutic algorithms is essential to avoid misdiagnosis, particularly in complex cases that can lead to erroneous interpretation. Despite its prevalence in the general population, including pediatric individuals, urologic dysfunction is still an underestimated health issue, and for this reason, it still deserves attention by the scientific community.

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