5 Principles of Voiding Cystourethrography (VCUG)

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Introduction

The voiding cystourethrogram (VCUG) is one of the most commonly performed studies in pediatrics. A VCUG is a fluoroscopic study that can assess the structure and function of the bladder and the structure of the urethra. It is frequently used in the evaluation of children with urinary tract infections to determine the presence of vesicoureteral reflux (VUR), bladder diverticula, complete bladder emptying, and to assess for possible bladder sphincter discoordination. VCUG is also performed in the evaluation of hydronephrosis, congenital renal anomalies, imperforate anus, cloacal abnormalities, disorders of sexual differentiation, trauma, and screening siblings for VUR. In addition, it provides information regarding the urethra and is used in diagnosing posterior urethral valves, urethral strictures, or suspicion of a duplicated urethra or other anomalies.

Vesicoureteral reflux (VUR) may lead to renal scarring. Neonates and infants are most susceptible, as the greatest risk of renal damage is during the first 2 years of life [1]. Reflux is the most common cause of antenatally detected hydronephrosis, accounting for up to 40 % of cases [2] and also is present in 30–50 % of children who present with a febrile UTI [3].

The study is performed in a fluoroscopic suite. The urinary bladder is catheterized and emptied. It is then filled with radiopaque contrast by gravity drip. At a minimum, images should include an early filling image, bilateral oblique images of the ureterovesical junction (UVJ) when the bladder is full, voiding images of the urethra, and post-void images of the kidneys and bladder. Depending on the child, the study can be performed with or without sedation. Careful technique is required to provide adequate images without exposing the child to unnecessary radiation.

Physics

The fluoroscopic equipment has several components: the x-ray generator, x-ray tube, collimator, filtration, grid, image intensifier, optical coupling, video camera, and the monitor as demonstrated in Fig. 5.1.

The x-ray generator allows for the selection of kilovolt peak (kVp) and tube current (mA) that is

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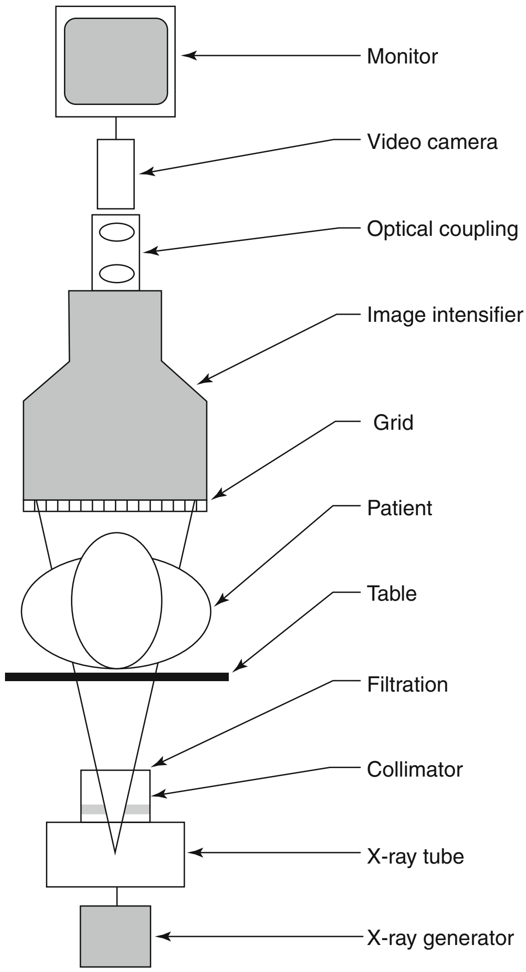

Fig. 5.1 Diagram shows the components of a fluoroscopic imaging chain [4] (Reprinted from Schueler [4]. With permission from Radiological Society of North America)

delivered to the x-ray tube. Generator types may be single phase, three phase, constant potential, and high frequency. Continuous or pulsed exposure is used to energize the tube. The main advantage of pulsed exposure is reduction in radiation exposure. There may be improvement in temporal resolution and decreased motion artifact. High-frequency generators provide superior exposure reproducibility and are the most compact and the cheapest, making them the most commonly used equipment [4].

The x-ray tube converts electrical energy produced by the generator into an x-ray beam.

The collimator defines the shape of the x-ray beam and limits the x-ray beam to the field of vision. The x-ray beam should be collimated to the area of interest to decrease the radiation to the tissue, therefore reducing the scatter produced and improving image contrast. When using collimation, it is important that the electronic collimation matches the manual collimation. Electronic collimation can mask critical information included on the image and cover up anatomy that is exposed [5].

Filters are used to attenuate low energy x-rays from the beam, which are absorbed by the patient but not transmitted to the image receptor. By absorbing these rays, filters aid in decreasing exposure to the patient.

Anti-scatter grids reduce the scattered x-rays reaching the image receptor, thereby improving the image contrast. However, this requires an increase in radiation exposure. Grids should be removed when performing studies where the scatter is low, particularly in pediatrics.

The image intensifier converts x-rays into a visible light image and amplifies the image brightness for better visibility [4]. Optical coupling distributes light from the image intensifier output window to a video camera and other image recording devices. A television system is used to view the image and a recording device stores the images.

Radiation Exposure and Radiation Safety

When using radiation, the ALARA principle, or *a*s *l*ow *a*s *r*easonably *a*chievable, should be implemented. This term was first used to refer to power plant and other radiation workers and has subsequently been applied to the medical imaging. Decreasing radiation exposure is especially important when children are involved as the radiation effects are cumulative, lifelong, and children are more sensitive to the effects of radiation. The linear no-threshold model of potential radiation damage means that any dose of radiation may cause some harm. Potential clinical effects of radiation exposure, in

Table 5.1 Potential clinical effects of radiation exposure

Skin effects	Threshold dose (Gy)	Time of onset
Early transient Erythema	2	2–24 h
Main erythema reaction	6	1.5 weeks
Temporary depilation	3	3 weeks
Permanent depilation	7	3 weeks
Dermal necrosis	>12	>52 weeks
Eye effects		
Lens opacity	>1–2	>5 years
Cataract	>5	>5 years

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addition to those of malignancies, are listed on Table 5.1.

When considering the use of radiation, first one should ask if there is a non-radiation alternative that can provide the information desired, such as ultrasound. For many of the indications for obtaining a VCUG, the answer is no. Next, one should focus on decreasing the amount of radiation exposure to the patient. This is where the ALARA principle is applied.

Three factors affect the radiation dose to health care workers as well as to the patient for any radiographic procedure: time, distance, and shielding.

Time refers to the duration the patient is under exposure. Radiation exposure is directly proportional to the duration of fluoroscopic time so one should be mindful of the amount of time exposures are collected. Having protocols in place for the timing and number of images obtained during a VCUG can decrease the amount of radiation administered. For example, for a routine VCUG, there is little value in obtaining images over the ureters during filling or voiding unless an abnormality is seen. Time is decreased by having experienced personnel perform the procedure and teach those who are learning. The use of stopwatches, alarm bells, or radio communication letting the operator know how long the machine has been used for can decrease the exposure time [6, 7]. Pulsed fluoroscopy reduces radiation exposure by decreasing the amount of time the beam reaches the patient compared with continuous fluoroscopy.

Distance refers to separation of the subject from the radiation source. Increasing distance decreases the radiation dose in an inversely proportional fashion. The radiographic exam table should be as far from the radiation source as possible, although this is a fixed distance in fluoroscopy. The patient should be as close as possible to the image intensifier to reduce the scatter, although this may need to be modified due to patient fright and inability to cooperate. A less cooperative patient can lead to increased exam and exposure time due to motion artifact, causing the need to repeat images.

Shielding not only benefits the patient but also reduces the intensity of the radiation reaching the worker [7]. Shielding refers to limiting the direction of the radiation source in the housing and to collimating the beam size to minimize the x-ray exposure and scatter; it may include using lead pads to protect parts of the patient not involved in the examination and includes leaded rooms and aprons to protect workers in and outside of the fluoroscopy room.

As mentioned previously, the use of grids should only be used when the body part thickness indicates their use (when body part thickness is more than 12 cm) and should be removed when not indicated [8], which is common in pediatrics.

A combination of features can markedly reduce the radiation exposure. By using low-frequency pulsed fluoroscopy, tight collimation, no magnification, and half-dose parameters, the reduction in effective dose can be as high as 90 % without sacrificing resolution [3, 6, 9]. Using high-quality image-capture technology can also reduce radiation dose [9, 10]. Modern techniques have decreased the radiation dose of fluoroscopic VCUGs from 100 times to 10 times the radiation dose compared to radionucleotide cystograms [3], although the radiation dose may vary with fluoroscopic VCUGs pending the number of images obtained.

Digital Fluoroscopy

As technology continues to advance, digital fluoroscopy is becoming the mainstay. Digital radiology uses x-ray sensors bonded onto thin-film transistor integrated circuits to instantaneously convert the image stored on the sensor to a visible digital image [11]. This can be either through direct detection, converting the x-rays into an electronic charge, or indirect, by converting the x-rays into light and then converting the light into an electronic charge. In film, optical density on the film is used as an exposure indication. With digital images, overexposed images are not as easily identified as underexposed images, resulting in unknowingly increased radiation exposure [8]. Underexposed images are easily identified by increased noise. However, overexposed images are sharp, and exposure cannot be assessed visually. Up to 43 % of pediatric digital images are overexposed [11]. Feedback on the exposure is provided by the exposure indicator at the image receptor. It is influenced by the part thickness, artifacts, source-to-image distance, collimation, grids, centering, image plate size, and equipment and detector design [8]. There is a tendency towards exposure creep, the gradual increase in the technician's selected exposure to obtain better quality images, as technicians need to repeat underexposed images [8]. In some areas, there is a trend towards exposure slide, where the radiologist accepts a nosier image until the image cannot be interpreted and needs to be repeated [5]. As a result, periodic checks by tracking exposure index and deviation index should be performed on a regular basis to assess for appropriate exposure.

Other challenges in digital imaging include the lack of standardization among vendors, lack of pediatric specific educational material and techniques, inability to use automatic exposure control in smaller children, and limitations of collimation and shielding of unnecessary body parts in smaller children [5]. Vendors of different machines have different exposure indicators; they have variable nomenclature and nonstandard units for reference values. In addition to the values being different, they may also be in inverse order so that the values may increase for overexposure for one manufactured and decrease for another [5]. Lastly, values provided may be inaccurate or uninterpretable in small children as indicated in Table 5.2. Technicians may be working with various types of machines in a given work day, making it more difficult to determine the amount of radiation being provided. These challenges are depicted on Table 5.3.

Table 5.2 Technical factors that can affect the exposure indicator (EI)

Size of detector/image receptor matched to patient size
Collimation and field size in relation to patient's body parts
Metal implants in patients (scoliosis rods, metal plates, screws, pacemakers)
Gonadal shield

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Despite these challenges, there are many advantages to digital radiography. The last image taken can be saved without having additional radiation exposure [3], post processing allows the radiologist to analyze various anatomical sites without needing additional images, the images can be stored and retrieved without losing image quality, and they can be accessed by various providers throughout a network.

Technical Considerations

Timing of VCUG

VCUGs needed for evaluation of a congenital anomaly can be obtained at any time. When a VCUG is necessitated following a urinary tract infection, previous recommendations were to delay the study by several weeks to allow the inflammatory process to resolve, as this may lead to detection of transient reflux secondary to ureteral dilation and inflammatory changes at the UVJ if performed too early [13, 14]. In addition, there also were concerns that if a VCUG is performed during an active infection, it may prolong the UTI or lead to bacterial dissemination and possibly sepsis [15]. Spencer [15] performed

Table 5.3 Suggested guidelines for QC action based on estimated incident exposure (conventional CR system for an "equivalent" speed class = 200)

Fuji (S No.)	Agfa (IgM)	Kodak(exposureindex)	Detector exposure estimate (mR)	Indication
>1,000	<1.45	<1,250	<0.20	Underexposed: repeat
1,000–601	1.45–1.74	1,250–1,549	0.2–0.3	Underexposed: QC exception
600–301	1.75–2.04	1,550–1,849	0.3–0.7	Underexposed: QC review
300–150	2.05–2.35	1,850–2,150	0.7–1.3	Acceptable range
149–75	2.36–2.65	2,151–2,450	1.3–2.7	Overexposed: QC review
74–50	2.66–2.95	2,451–2,750	2.7–4.0	Overexposed: QC exception
<50	>2.95	>2,750	>4.0	Overexposed: repeat if necessary

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Abbreviations: *IgM* log of median exposure, *QC* quality control, *S number* sensitivity number

a retrospective review of VCUGs obtained over a 5-year period in all children admitted with a febrile UTI. Children were divided into two cohorts: those with an early VCUG, performed within the week of diagnosis after appropriate antibiotics had been initiated (67 patients), and those with a late VCUG, performed more than 1 week after diagnosis (65). All patients were followed for a period of 5 years after discharge to assess for complications. The incidence and severity of VUR were similar in the two groups. The early group showed no sign of worsening illness after the test was performed and had similar ED and hospital admissions rate as the late group. One hundred percent of the patients in the early group had their VCUGs done vs. 77 % in the late group ($p = 0.005$). These findings suggest that VCUGs can be obtained safely after appropriate antibiotics have been instituted and that compliance rates are better when the test is performed early, especially if it performed during an acute hospitalization. This could also be beneficial for children with recurrent episodes of pyelonephritis, who may only reflux during an active infection.

Patient Preparation

VCUGs are considered to be one of the most stressful urologic studies performed for both patients and parents [9, 16] with up to 27 % of patients experiencing severe distress [17] and 71 % of children experiencing serious or severe distress or panic on the Groningen Distress Rating Scale [16]. Distress may be secondary to the catheterization, but also may be related to fear of the unknown. Unexpected stress is more anxiety provoking and more difficult to deal with than anticipated or predicted stress [9]. Srivastava et al. [18] found that parents anticipated their child would experience more fear than they observed ($p = 0.04$), tended to anticipate that their child would suffer more distress than observed ($p = 0.08$), and anticipated that their child would suffer far more distress after the VCUG than they observed ($p < 0.01$). There was a significant correlation between the parents' anxiety and their perception of the severity of their child's fear ($r = 0.52$, $p = 0.009$), distress ($r = 0.48$, $p = 0.017$), and pain ($r = 0.50$, $p = 0.01$) during the procedure.

Preparation of both the parent and the child via education can help decrease perceived anxiety and stress levels for the parents and the child [19, 20]. Education can be in the form of reading materials or videos. In some centers, children are given a tour and allowed to sit on the table while a doll is catheterized as the procedure is explained so they know what to expect and are given an opportunity to ask questions. After determining that VCUGs were one of the most stressful studies performed at their institution partly due to lack of information, Phillips et al. [16] sought to

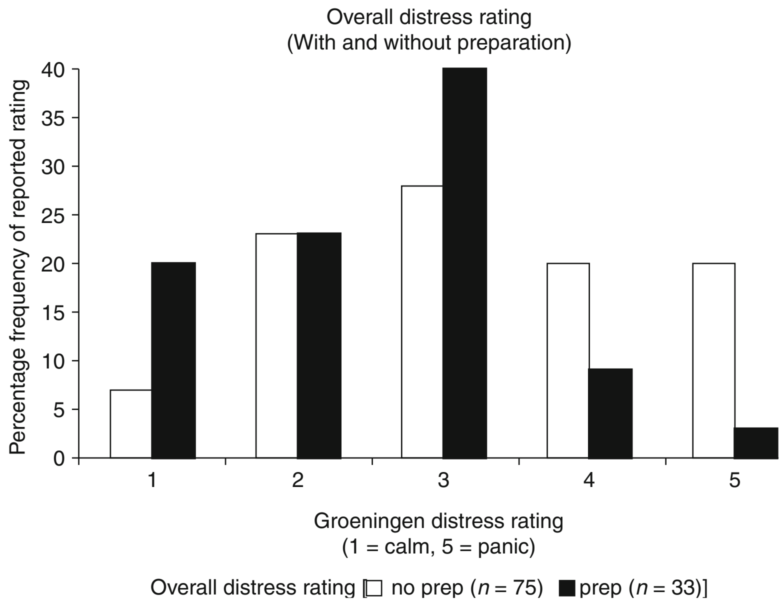

Fig. 5.2 Overall distress rating (with and without preparation) [16]. Legend: *White bar*, no prep ($n = 75$); *black bar*, prep ($n = 33$). Groningen Distress Rating Scale: *1*, calm; *2*, mild distress; *3*, serious distress; *4*, severe distress; *5*, panic (Reproduced from Phillips [16]. With kind permission from Wiley)

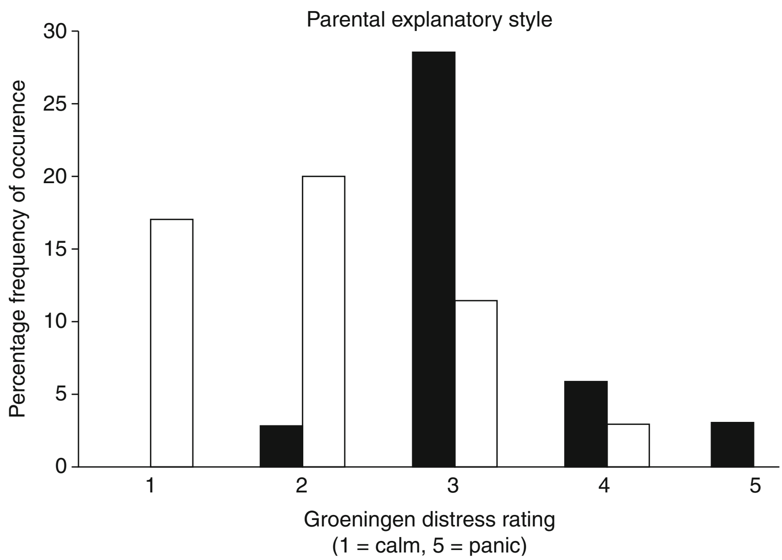

Fig. 5.3 Parental explanatory style [16]. Legend: *Black bar*, avoid/omit; *white bar*, describe in full. GDRS = *1*, calm; *2*, mild distress; *3*, serious distress; *4*, severe distress; *5*, panic (Reproduced from [16]. With kind permission from Wiley)

determine if better patient preparation would alleviate parental and patient distress. They had two intervention groups and compared their distress level to their historic controls. One intervention group was given a story book describing the procedure and expectations, while the second group was given the book as well as play therapy where they had the procedure explained with the aid of a gender appropriate doll. The child's distress was significantly reduced with preparation ($p = 0.0026$) with a median distress score on the Groningen Distress Rating Scale of 2.5 in the preparation group vs. 3.3 in the controls (Fig. 5.2). Among the preparation group, children had lower distress scores when parents provided full disclosure compared to those where parents avoided or omitted upsetting details ($p = 0.0025$) (Fig. 5.3). Between the two preparation groups, there was no difference in distress scores with the addition of play therapy.

During the procedure, a calm parent should be allowed to accompany the child as this decreases patient distress [16]. Parents can help their child by providing support and distracting them with toys, videos, balloons, etc. In addition, children depend on their parents to help them cope with stressful situations [16]. Children have been found to be more cooperative and calm with invasive procedures when supported by their parents and prompted to model coping behaviors [16]. The use of child life specialists when available is also recommended.

The Role of Sedation

Despite appropriate preparation, some patients may still exhibit high levels of distress when having a VCUG, particularly if they have had a previous negative experience such as prior catheterization or if there are other external circumstances. During these situations, sedation may be useful. There are several concerns regarding the use of sedation: cost, time, safety, and effects sedation can have on bladder dynamics. Herd found that the increased costs were related to the need for a recovery room and staff and that safety was excellent in the context of experienced staff with proper equipment and available emergency preparations [21]. In a randomized trial of sedation vs. placebo, sedation added approximately 60 min to the entire procedure, mostly as recovery time [22]. There was no significant difference in the filling or voiding phase, and there was no difference in the volume infused between the two groups [22]. VUR was identified in 16 % of children, without difference between the two groups ($p=0.31$).

Although the use of sedation increases the overall procedure time, sedation is useful in decreasing anxiety and distress among children older than 1 year and their parents. In a randomized double-blind controlled trial of oral midazolam 30 min prior to catheterization at a dose of 0.5 mg/kg vs. placebo, 61 % of children experienced serious or severe distress in the placebo vs. 16 % in the treatment group, with the NNT being 2.9 (Fig. 5.4) [22]. When the test was divided into parts (entering the room, catheterization, filling, voiding, and leaving the room), there were differences in distress detected at entering the room ($p=0.01$), filling ($p=0.0001$), and voiding ($p<0.0001$), and no difference detected at catheterization ($p=0.10$) and leaving the room ($p=0.18$) as depicted in Fig. 5.5. Both groups were provided educational pamphlets and offered play therapy prior to the procedure. In review of five comparative studies, the use of midazolam significantly lessened distress without affecting voiding dynamics or having adverse effects [21].

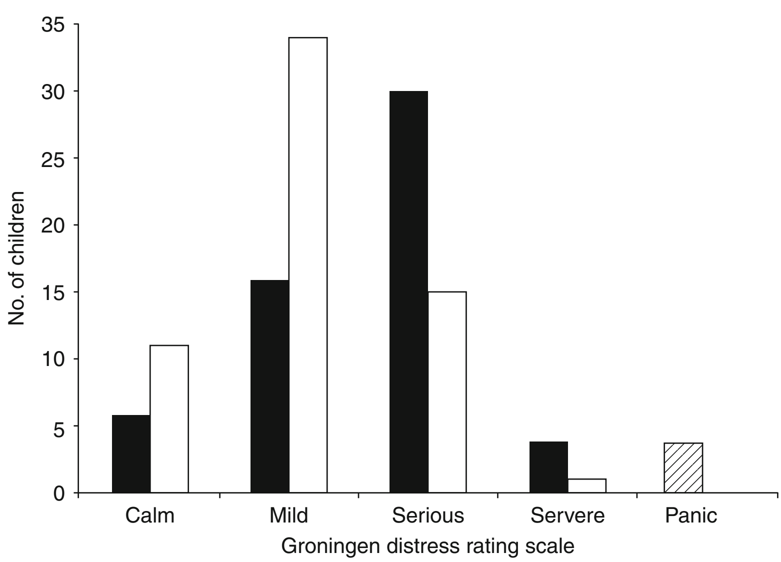

Fig. 5.4 Distress levels at any stage during voiding cystourethrography [22]. *Bar graph* shows peak distress score at any stage during voiding cystourethrography (VCU) ($n=117$). Fifty-six received placebo (*black bars*) and 61 received midazolam (*white bars*). *Striped box* represents four children – all of whom were in the placebo group – who failed to complete VCU due to panic (From Herd et al. [22]. Reprinted with permission from the American Journal of Roentgenology)

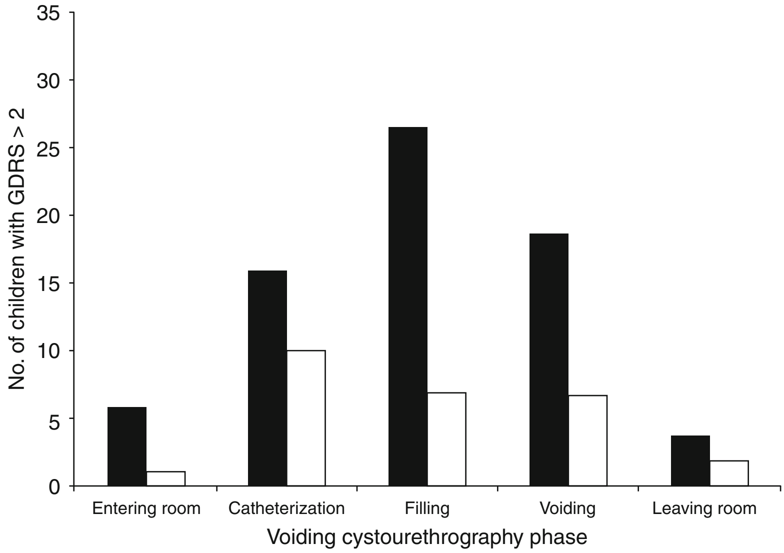

Fig. 5.5 Distress levels at different phases of a voiding cystourethrography [22] *Bar graph shows number of children (n = 117) who experienced serious or severe distress* (Groningen Distress Rating Scale [GDRS] score > 2) at each phase of voiding cystourethrography. Fifty-six received placebo (*black bars*) and 61 received midazolam (*white bars*) (From Herd et al. [22]. Reprinted with permission from the American Journal of Roentgenology)

Ferguson randomized children to midazolam 15 min prior to the procedure vs. placebo in a double-blind fashion and found no difference with the use of midazolam at decreasing anxiety in children or in their secondary outcomes of the degree of parental anxiety, health care professional perception, and post-procedure behavior outcomes [23]. It is possible that the differences may be secondary to a smaller sample size, decreased wait time to the procedure, or the use of different assessment tools.

The use of nitrous oxide and propofol has also been studied. In a retrospective study of the use of propofol, there was a decreased ability in children to completely void, which may interfere with the diagnosis of VUR [24]. Keidan et al. compared 50 % nitrous oxide in 23 children to 0.5 mg/kg oral midazolam in 24 children; there was no placebo group [21]. They did not find a significant difference in the two groups. There was a trend towards longer time to void in the nitrous group (15.3 min vs. 7.2 min), although this was not significant ($p = 0.8$), but those in the nitrous group had a faster recovery time (29 min vs. 63 min, $p < 0.001$). Zier used 70 % nitrous for catheterization only in 107 older children and compared this to 107 children without the use of sedation. FACES scale was 6 for the nonsedated group and 0 for the sedated group ($p < 0.001$) immediately after catheterization and the Brief Behavioral Distress Scores were 44 in the nonsedated group vs. 11 for the sedated group ($p < 0.001$) [21].

Overall, the use of sedation can help alleviate distress in older children and does not appear to affect bladder dynamics or detection of VUR. It is safe when used appropriately and with experienced staff in a setting where emergency protocols are set in place.

Catheterization

Catheterization of the urethra should be performed using strict aseptic technique. An 8 French feeding tube should be used instead of an indwelling catheter as having an inflated catheter balloon can be falsely mistaken for a ureterocele. For older children, a larger catheter can be used, and a smaller one for premature or very small infants. The catheter should be advanced no further than 1–2 cm after urine is obtained to prevent injury to the bladder or the formation of a knot in the tube. The catheter should be secured and a urine sample sent for aerobic culture and sensitivity, as up to 3 % can be positive for a urine infection [9]. Alternatively, a urine dip can be performed and cultures sent for those specimens that are positive for leukocytes and/or nitrites [9]. In uncircumcised newborns, the foreskin should not be forcefully retracted. It is imperative that the phallus not rest over a urinal, as this may cause external compression of the urethra giving a false impression of urethral obstruction. In boys, the external sphincter is the most common site of resistance. Applying gentle, steady posterior pressure can help advance the catheter into the bladder. Also, advancing the catheter when he takes a deep breath may facilitate placement. If he voids during catheter placement, maintain a hold of the catheter and continue to advance, since the urethra is open during voiding. In girls, good retractions of the labia with the aid of soft gauze can help visualize the meatus midline, just anterior to the vagina. Two percent lidocaine jelly can be used to decrease sensation in older children but needs to be placed several minutes prior to catheterization in order to take effect.

There is some debate as to whether the catheter should remain in or be removed during the voiding phase of the VCUG. The main concern about leaving the catheter in place is possibly missing posterior urethral valves (PUV). To address this question, Ditchfield et al. performed a retrospective study of the preoperative VCUGs performed in a consecutive series of 48 boys with cystoscopically proven PUV [25]. The VCUGs were independently reviewed by three radiologists. The catheter was left in place during voiding in 28 (58 %) and removed in 17 (35 %). Three patients (6 %) had the study performed with and then without a catheter. PUV were detected in 25 (89 %) of the 28 with a catheter and 15 (88 %) without the catheter. Five boys were found to have PUV on cystoscopy, but the VCUG did not have a dilated posterior urethra or "other evidence of obstruction." Of those 5 boys, 3 had the VCUG performed with a catheter, and 2 had it without a catheter. In the three boys that had the VCUG performed with and without the catheter, PUV were detected in both studies. Overall, there was no difference in the detection of PUV if voiding took place with or without a catheter as demonstrated on Table 5.4.

There are several benefits to leaving the catheter in place during voiding: cyclic exams would not require re-catheterization, exams can be repeated if the results are equivocal or there are technical failures, and the bladder can be distended until the patient initiates voiding. In addition, if there is contrast remaining in the upper tracts, the bladder can be drained to determine if the residual contrast is due to continuous reflux or secondary obstruction [25, 26].

Table 5.4 Diagnostic findings of posterior urethral valves at voiding cystourethrography according to whether a catheter is in place during voiding

	No (%) of patients	Dilated posterior urethra (% of cases with finding)	Visible valves (% of cases with finding)
Catheter	28 (58)	25 (89)	19 (68)
No catheter	17 (35)	15 (88)	5 (29)
Both	3 (6)	3 (100)	3 (100)
Total	48 (100)	43 (90)	27 (56)

From Fernbach et al. [26]. Reprinted with permission from the American Journal of Roentgenology

Contrast Media

Low-osmolar contrast material should be adequate. Dilute contrast is useful when trying to outline the presence of the ureterocele as concentrated contrast at large volume may obscure its detection. Taking into account the effects on the bladder and children's distress to cold (room temperature) contrast on children's distress and on the bladder, ideally the contrast material should be warm (body temperature). Receptors located within the bladder mucosa and trigone are responsible for a very sensitive cooling reflex [9]. They stimulate unmyelinated C-afferent fibers in the pelvic and pudendal nerves that consequently stimulate a detrusor contraction [27]. As a result, infusing the bladder with cold fluid can cause the bladder to empty at smaller volumes [9, 27]. This reflex is usually suppressed by 4 years of age [27]. When looking at distress levels in children under 1 year of age, 72 % of children having warm instillation had minimal distress vs. 48 % having cold instillation (Fig. 5.6) [27].

Contrast media should be infused slowly under gravity via the catheter and not injected

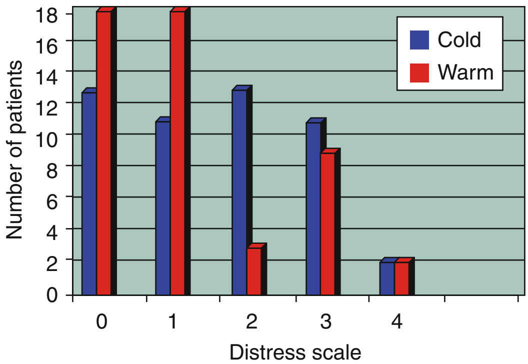

Fig. 5.6 The variation in perceived distress using warm or cold contrast medium [27]. Scale = *0*, no distress; *1*, flinching during infusion only; *2*, mild dress, crying < 50 % of examination; *3*, moderate distress, crying > 50 % of examination; *4*, severe distress, crying throughout the examination (Reprinted from Goodman et al. [26]. With permission from Elsevier)

under pressure. This will decrease bladder spasms and also is less likely to cause transmucosal absorption and subsequent potential contrast reaction [9, 26]. As bladder capacity is reached, the flow may slow down, stop, or even reverse [26]. Some advocate filling the bladder at a rate of 2 ml/kg/min at a pressure of 40 cmH_2O [28]. However, there are no universal protocols regarding the instillation of contrast. Palmer surveyed 41 institutions regarding their methodology [29]. The majority of discrepancy between institutions was on the height of the contrast material and on the formula used to estimate bladder capacity (EBC) in children less than 2 years of age. There was a 90 % consistency rate on infusing the contrast material under gravity, using feeding tubes or catheters without the balloon inflated, using non-diluted contrast, allowing parents in the room, and removing the catheter at the onset of voiding [29]. The Koff formula [EBC (mL) = (age +2) × 30)] is commonly used to estimate bladder capacity in children greater than 2 years of age. Twelve percent of the institutions surveyed stopped infusing at EBC. However, younger children tend to have larger bladder sizes than predicted, and some children reflux at volumes larger than predicted [28, 29]. In addition, children with voiding or bladder dysfunction may have larger than expected bladder capacity. As a result, stopping the infusion at EBC instead of at the start of voiding may lead to false negatives and may miss important clinical information. If voided volumes are lower than expected, one should consider refilling the bladder [26] as VUR may not be detected if the bladder is underdistended.

Images

No universal protocols exist regarding the performance of a VCUG. As previously stated, images should include (a) an early filling image, (b) bilateral steep oblique images of the ureterovesical junction (UVJ), including the trigone or the presumed location of the distal ureters, when the bladder is full, (c) voiding images of the urethra, and (d) post-void images of the kidneys and bladder. Additional views of the bladder and kidneys during repeated filling and voiding can detect subtle abnormalities, such as intermittent VUR. If reflux is present, delayed images of the kidneys can determine how well the system drains. The scout image, if performed, should include assessment of the spine and pelvis looking for spinal dysraphism, sacral agenesis, scoliosis, or other abnormalities as seen in Fig. 5.7. Masses, stones, or foreign bodies may be seen. Figure 5.8 depicts large renal calculi seen on the scout film. Colonic gas pattern and volume of stool should be assessed as constipation may play a significant role in the underlying urologic problem.

Early fill AP coned down view of the bladder may detect a ureterocele, as seen on Fig. 5.9, or a filling defect that may represent a bladder mass, clot, or other pathology. Correct catheter placement should be confirmed during this phase of the study.

The full bladder is evaluated with steep oblique images, coned to the posterior bladder and trigone, and the expected location of the distal ureters (Figs. 5.10 and 5.11). These images evaluate

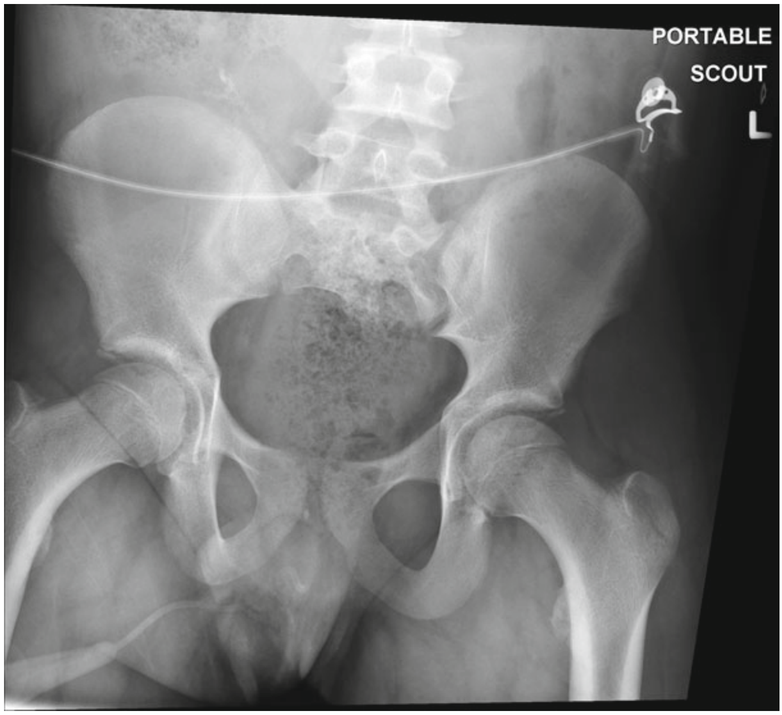

Fig. 5.7 Scout film demonstrating sacral agenesis in a boy with a neurogenic bladder

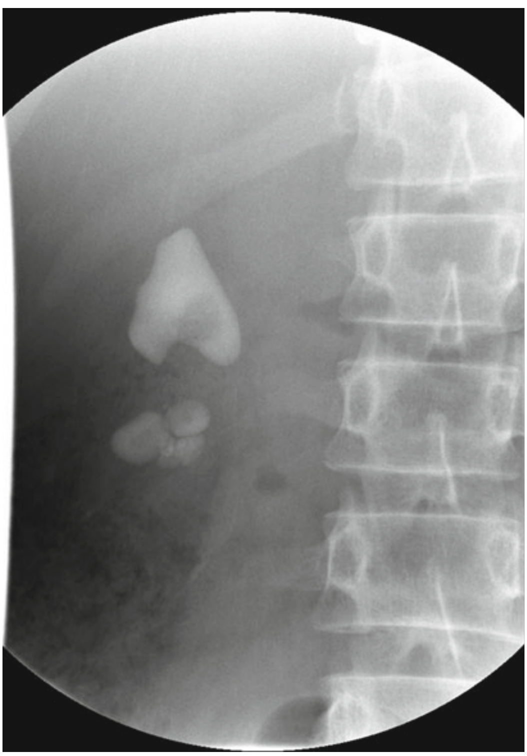

Fig. 5.8 Scout film with large renal stones

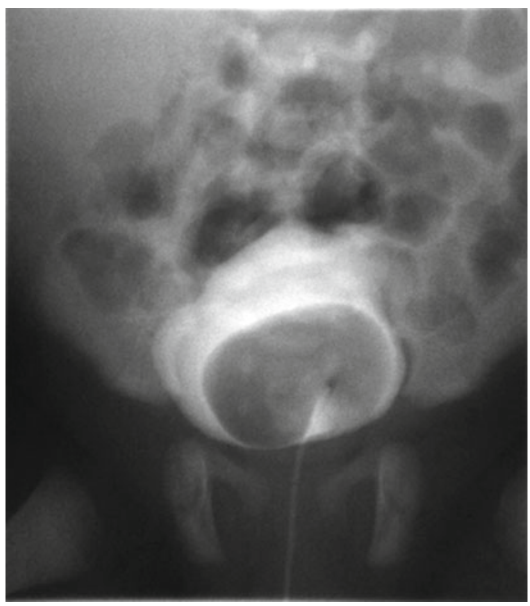

Fig. 5.9 Large ureterocele seen in an infant with a history of hydronephrosis

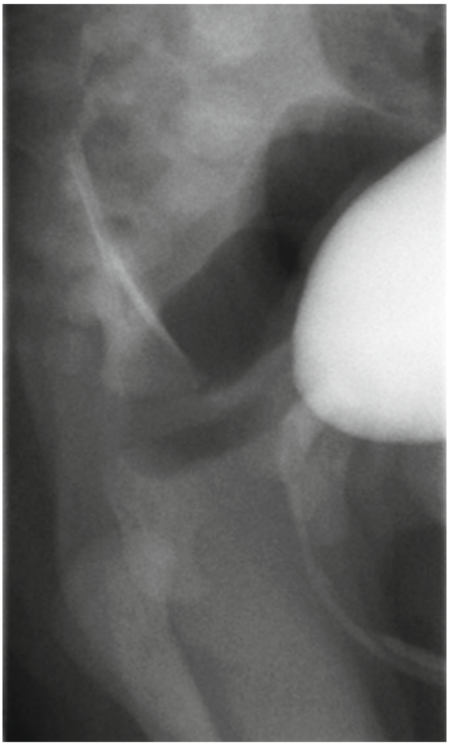

Fig. 5.10 Oblique film demonstrating no evidence of reflux on the right

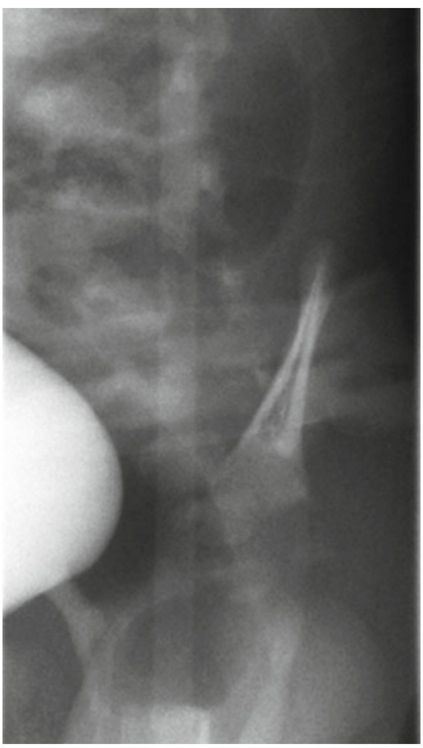

Fig. 5.11 Oblique film showing no evidence of reflux on the left

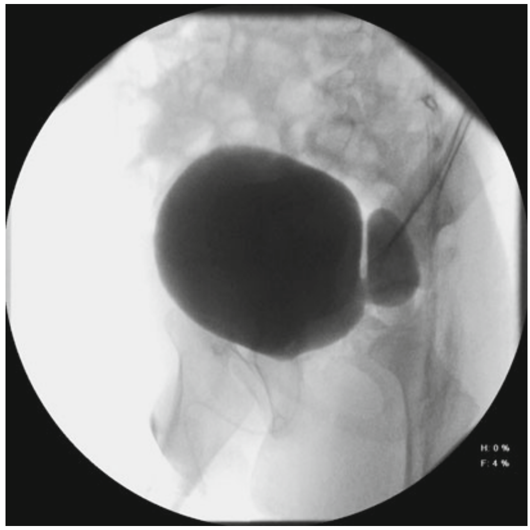

Fig. 5.12 Oblique view demonstrating a diverticulum. Diverticula may be congenital or may be secondary to high-pressure voiding or a neurogenic bladder

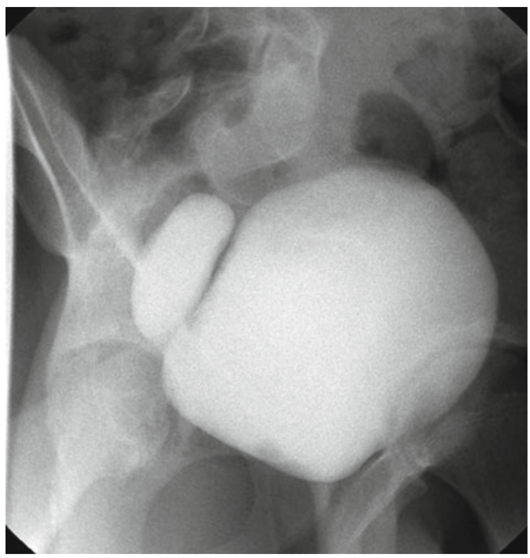

Fig. 5.13 Oblique image demonstrating a bladder diverticulum

for low grade VUR, everting ureteroceles, diverticula, or other bladder anomalies (Figs. 5.12, 5.13, 5.14, 5.15, and 5.16). Additional assessments include bladder capacity, contour, presence of trabeculations, and emptying capability [26]. Figure 5.17 demonstrates a classic appearance of a neurogenic bladder with high-grade VUR.

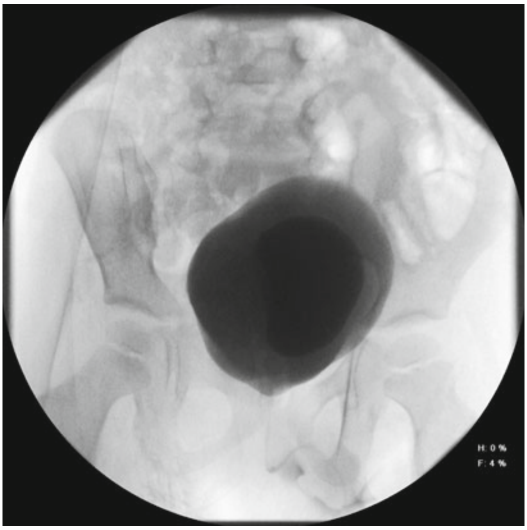

Fig. 5.14 AP view of a bladder diverticulum. With more concentrated contrast, the diverticulum could be missed in this view

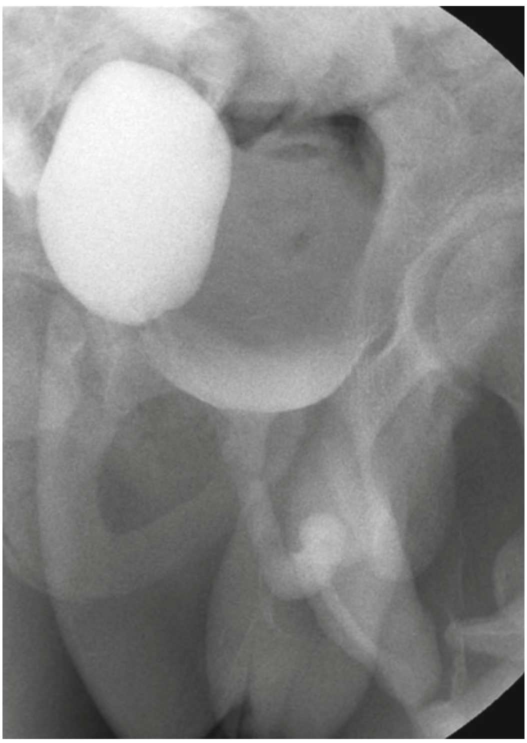

Fig. 5.15 Voiding image demonstrates filling of a diverticulum during voiding with a rim of contrast seen at the base of the bladder

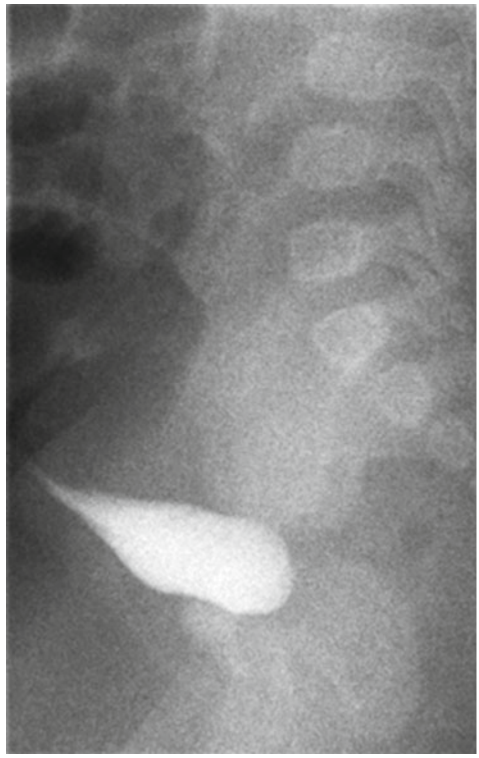

Fig. 5.16 Patent urachal sinus

Fig. 5.17 Neurogenic bladder demonstrating a classic Christmas tree appearance secondary to trabeculations and sacculations. The refluxing ureter is dilated and tortuous

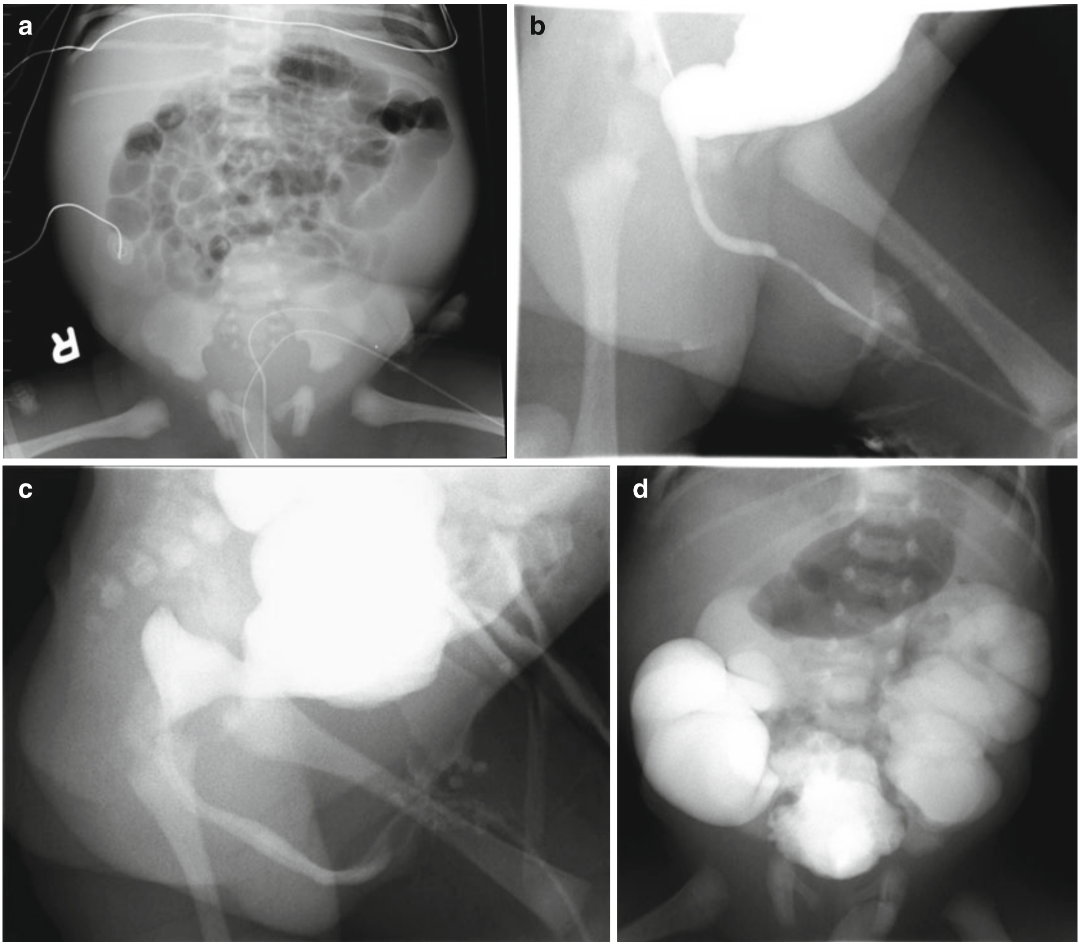

Fig. 5.18 (**a**) Scout film of a patient with Eagle-Barrett (Triad) syndrome demonstrated a protuberant abdomen and flared ribs. (**b** and **c**) Voiding images of a two patients with Eagle-Barrett demonstrating a patent urethra with a dilated posterior urethra and an enlarged smooth bladder with trabeculations. (**d**) Post-void images demonstrating massive VUR with incomplete emptying in a patient with Eagle-Barrett syndrome. Eighty-five percent of patients with Eagle-Barrett syndrome will have VUR [2]

Other bladder anomalies may be demonstrated as seen on Fig. 5.18, taken of a child with Eagle-Barrett syndrome and Fig. 5.19, taken of a child with a common urogenital sinus.

If present, VUR should be reported based on the International Reflux Study Committee's classification (Table 5.5, Figs. 5.20, 5.21, 5.22, 5.23, 5.24, 5.25, and 5.26). The grade of reflux is determined on the most severe VUR seen, which usually, but not always, coincides with the peak of voiding [2]. Insertion site of the refluxing ureter as well as the timing of VUR should be stated as this may have prognostic implications, as seen on Figs. 5.27 and 5.28. High-resolution renal images should be obtained pre- and post-void to assess for VUR, especially if no obvious reflux is seen on fluoroscopically saved images. Reflux is most likely to occur during voiding. Approximately 20 % of reflux will be missed if voiding does not occur [26]. Intrarenal

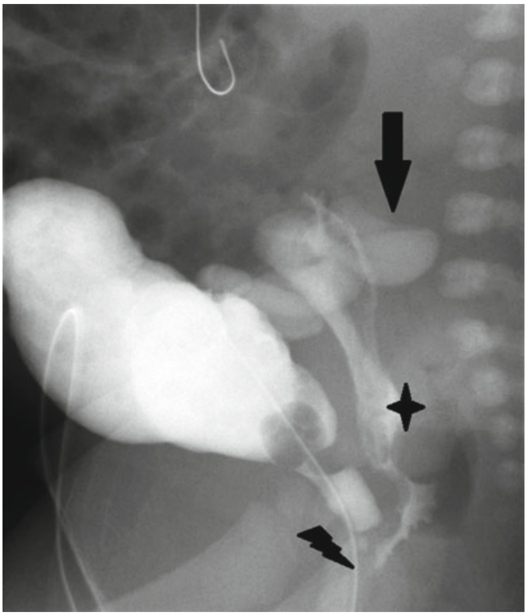

Fig. 5.19 VCUG obtained in a child with a common urogenital (*UG*) sinus. The *thick arrow* indicates associated VUR. The *lightning bolt* demonstrates the common UG sinus. The *Star* depicts contrast entering the vagina

Table 5.5 International Reflux Study Committee's grading of vesicoureteral reflux

Grade I	Reflux into the ureter only
Grade II	Reflux into a non-dilated ureter and pelvicalyceal system
Grade III	Reflux into a mild or moderately dilated ureter and collecting system with no or very minimal blunting of the fornices
Grade IV	Reflux into a moderately dilated ureter and system with blunting of the fornices but preservation of the papillary indentations
Grade V	Reflux into a grossly dilated ureter and system with loss of the papillary indentation

reflux may be demonstrated on VCUGs. This is demonstrated by contrast seen within the renal parenchyma in addition to the collecting system. This should be reported as it has prognostic implications for renal scarring, hypertension, and long-term renal function (Fig. 5.29).

Voiding images should be obtained in an anterior oblique position for males and AP or oblique position for females (Figs. 5.30 and 5.31) [26]. During voiding, the caliber of the urethra should be evaluated as well as the presence of VUR. Figure 5.32 demonstrates posterior urethral valves in a boy with a history of bilateral hydronephrosis. He had bilateral VUR with rupture of a calyx on the right, causing a right-sided urinoma, as seen on Fig. 5.33. Other urethral anomalies include urethral duplication and megalourethras as seen in Figs. 5.34 and 5.35.

Coordinated voiding between the bladder neck and external sphincter and the caliber of the bladder neck should be assessed, particularly in girls and patients with a neurogenic bladder. Figure 5.36 demonstrates a spin top urethra seen in female with dysfunctional voiding, and Fig. 5.37 demonstrates some reflux of contrast in the vaginal vault. This is frequently seen in infants, and in older patients may be a sign of vaginal trapping of urine during voiding, which could be a source of recurrent urinary tract infections.

Post-void images of the kidneys in an AP view are obtained to assess for VUR. These images should be performed soon after the patient stops voiding, even if the bladder has not completely emptied. Quickly draining vesicoureteral reflux may be missed, if the patient is allowed to void in the restroom instead of on the table or there are

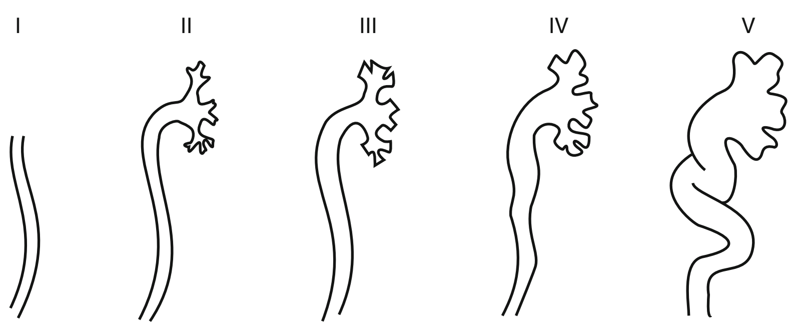

Fig. 5.20 International Reflux Study Committee's grading of vesicoureteral reflux

Fig. 5.21 Grade II left VUR

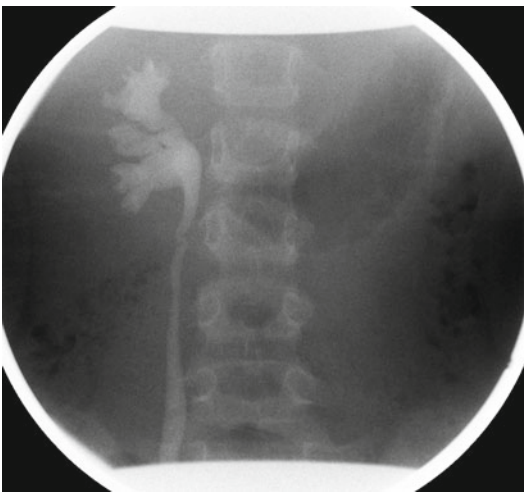

Fig. 5.22 Grade III right VUR

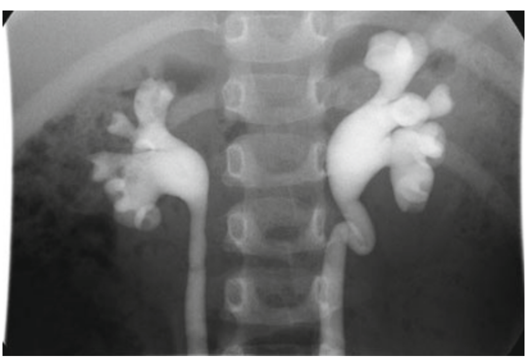

Fig. 5.23 Bilateral grade IV VUR, worse on the left with stool seen in the colon

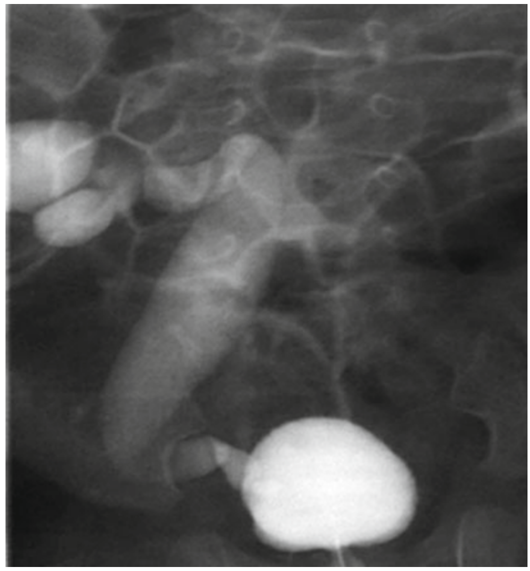

Fig. 5.24 VUR into the right tortuous lower pole ureter and calyces. Note dilution of contrast in a dilated ureter by retained unopacified urine

Fig. 5.25 Grade V right lower pole VUR

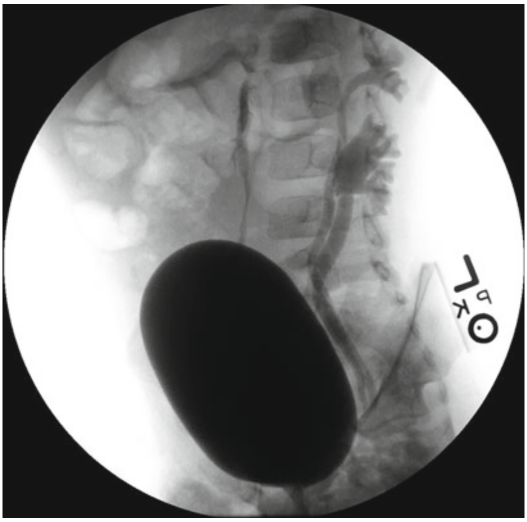

Fig. 5.26 Grade I right VUR with left VUR into a duplicated system

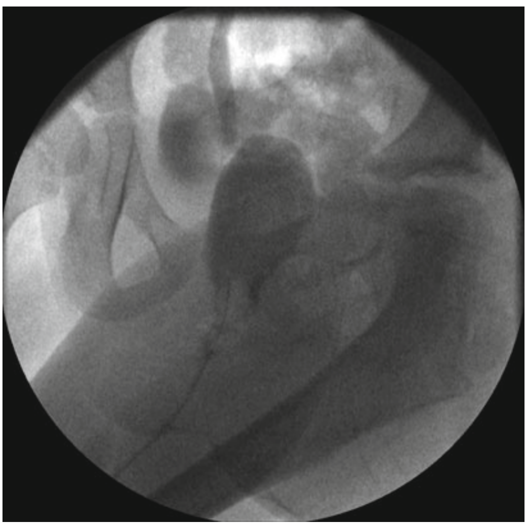

Fig. 5.27 Catheter inadvertently placed in the vagina opacifying a normal appearing vagina with a refluxing ectopic right ureter

other delays in obtaining the post-void images. If high-grade VUR, grades IV or V, is present, then delayed images should be performed approximately 15 min after voiding to assess for underlying UPJ or UVJ obstruction (Fig. 5.38).

In addition, post-void bladder images assess for complete emptying. It is important to note that the majority of infants do not empty to completion

Fig. 5.28 Views of the bladder in the same patient as Fig. 5.27, demonstrating no evidence of VUR from the urinary bladder

[32]. If the patient double voids, repeat post-void images of the kidneys and bladder should be obtained. It is important to note the presence of contrast in the vagina (Fig. 5.37) which could be normal pooling artifact from supine voiding, but might account for symptoms of post void wetness, vaginitis, or false-positive bacterial growth in non-catheterized urine samples.

Cyclic VCUG

Cyclic VCUGs entail having the bladder fill and having the patient void several times. When performing a cyclic VCUG, most will leave the catheter in place. Repeat images of the bladder

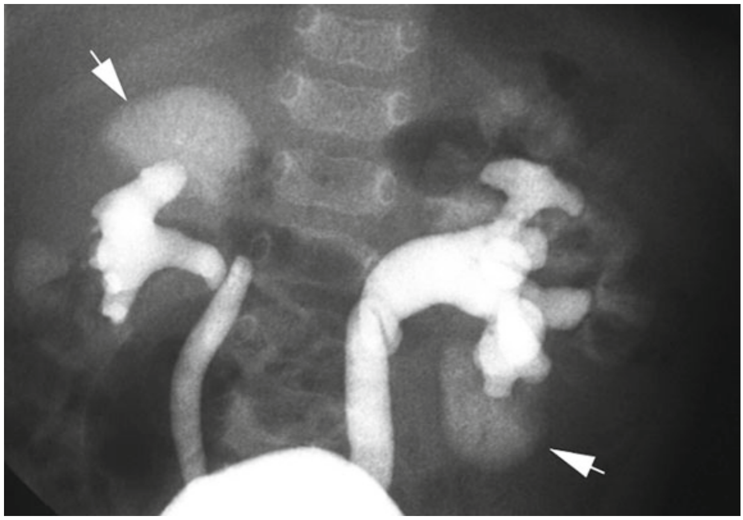

Fig. 5.29 Intrarenal reflux demonstrated by the *arrows* (Reproduced from Kanumakala et al. [30]. With permission from BMJ Publishing Group LTD)

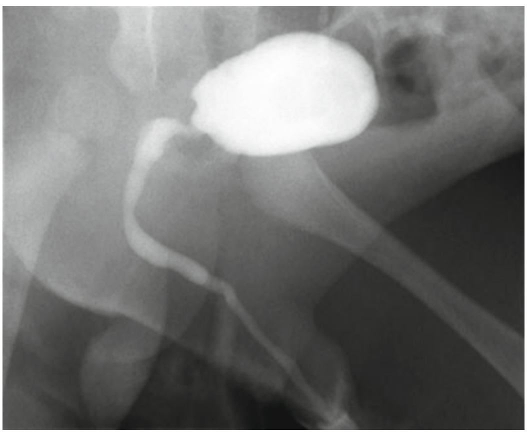

Fig. 5.30 Normal male urethra

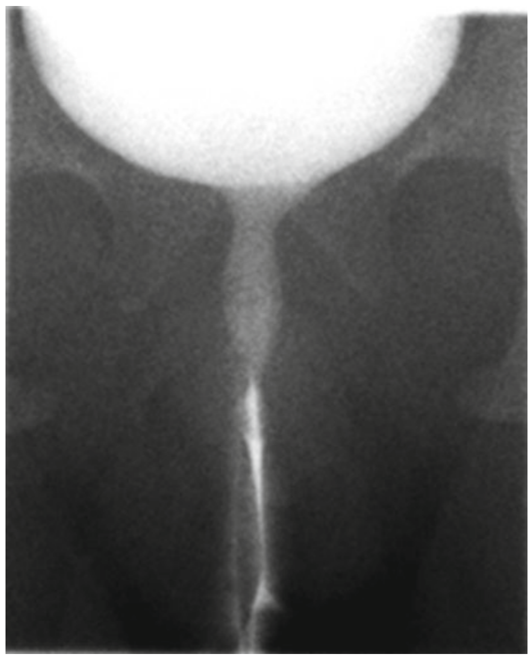

Fig. 5.31 Normal female urethra

and kidneys during voiding and post-void are performed. As VUR can be intermittent, cyclic studies increase the yield of detecting VUR up to 20 % [9, 33], most of which have been grade II or higher. In addition, the grade of VUR detected may be higher on the second cycling phase [9, 33]. Cyclic studies are encouraged for children under the age of 5 years, in children in whom VUR is suspected, or in patients with a suspected ectopic ureter [34]. Also, cyclic studies should be performed in children who spontaneously void at low volumes, as this may be secondary to bladder spasms, and the child may reflux at higher volumes in a normal physiologic state. If an ectopic ureter is draining into the bladder neck, it may first need to empty prior to seeing contrast material refluxing into the ureter, and only minimal contrast may reflux. This contrast may be further obscured by vaginal reflux. If a second voiding cycle is not performed, this refluxing ureter may be missed. Several cycles and having the patient in an oblique position may increase the changes of detecting the refluxing ectopic ureter [34].

Fig. 5.32 Post-void image in a patient with posterior urethral valves. Typical findings of a dilated, elongated posterior urethra with a filling defect at the level of the obstruction are demonstrated by the *arrow*. The catheter is curled in the posterior urethra. The bladder is empty demonstrated by the *star* and there is bilateral VUR

Complications

VCUGs are generally a low-risk procedure. One of the main considerations includes radiation exposure as stated previously. Catheter-related complications include dysuria, perineal discomfort, urinary retention, hematuria, creation of a false passage, perforation, or knotting of the catheter that may require surgery. In addition, catheters may be placed in the vagina, ureteral orifice, prostatic utricle, or a ureterocele leading to misinformation [35]. Instrumentation may cause a urinary tract infection and rarely lead to sepsis [36]. There may be an allergic reaction to latex or to the contrast material if it is absorbed.

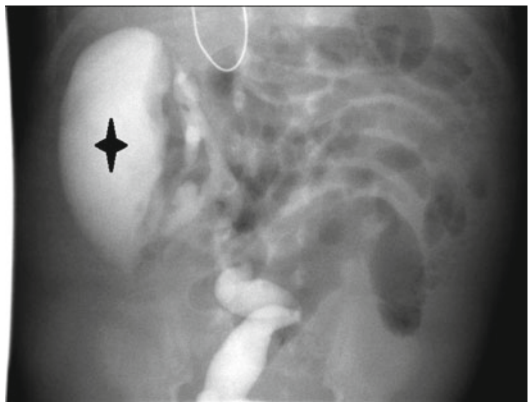

Fig. 5.33 Urinoma (*star*) due to a calyceal rupture in the same patient with VUR secondary to posterior urethral valves

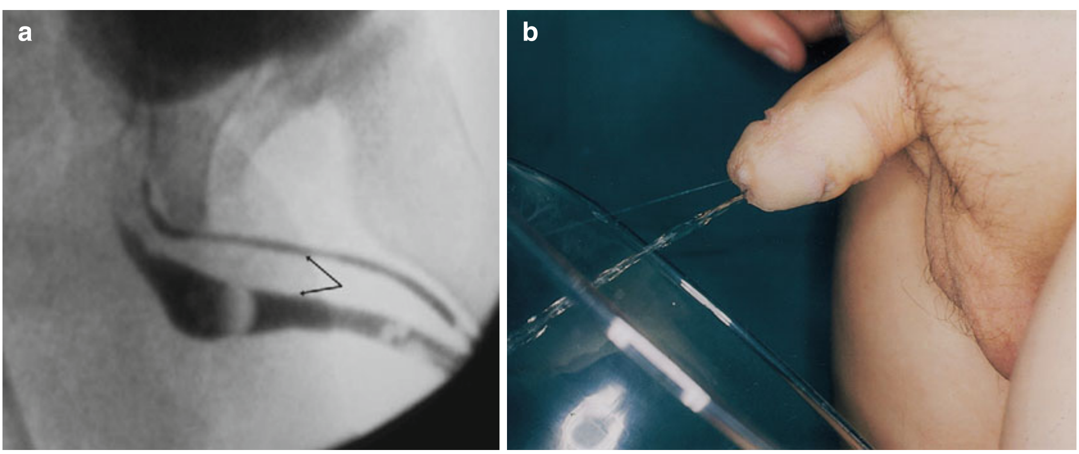

Fig. 5.34 (**a**) VCUG demonstrates contrast traveling through a complete urethral duplication (*two arrows*) (Reprinted from Palmer [31]. With permission from Elsevier). (**b**) Clinical photograph obtained in a 13-year-old boy during voiding shows complete urethral duplication (Reprinted from Berrocal et al. [2]. With permission from Radiological Society of North America)

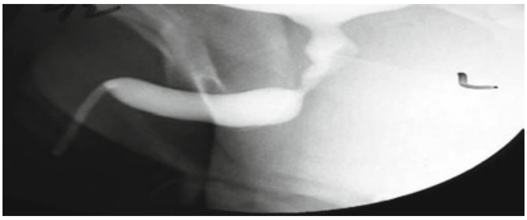

Fig. 5.35 Saccular-type megalourethra (Reprinted from Palmer [31]. With permission from Elsevier)

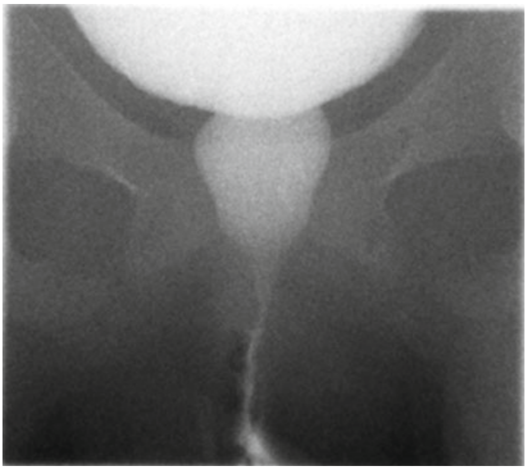

Fig. 5.36 Spin top urethra associated with dysfunctional voiding

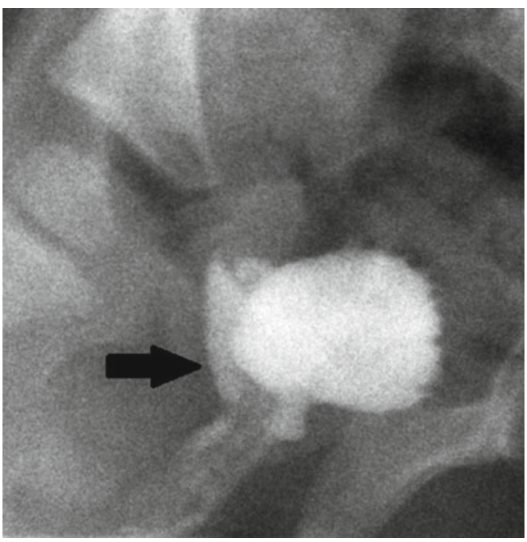

Fig. 5.37 Vaginal reflux of contrast depicted by the arrow

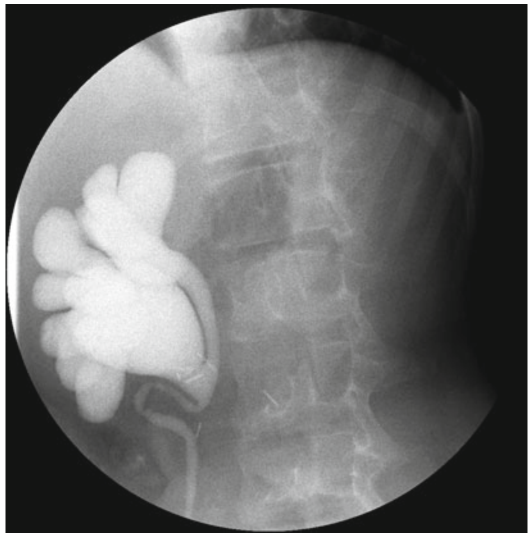

Fig. 5.38 VUR into a bifid system. There is "J hooking" of the ureter at the level of the UPJ with a disproportionally dilated renal pelvis to the ureter suggestive of an underlying UPJ obstruction

Special considerations should be made in patients with a spinal cord injury to avoid autonomic hyperreflexia (dysreflexia), which is potentially fatal. Autonomic hyperreflexia can occur in patients with a lesion above the sympathetic outflow, which is usually around T6 but has been reported as low as T10. There is a sympathetic surge secondary to a noxious stimulus below the level of the lesion. As a result of this surge, patients may have flushing of the face and body above the lesion and sweating. Cardiac symptoms include bradycardia and hypertension that can cause headaches or if more severe, cerebral hemorrhaging or seizures. Less frequently tachycardia and arrhythmias may occur. Symptoms usually resolve quickly once the stimulus is removed. During a VCUG, the noxious stimulus is frequently a full bladder. If these symptoms occur, the study should be aborted and the bladder drained. In patients with a known history of autonomic hyperreflexia, prophylaxis and proper monitoring should be instituted if the study is absolutely necessary.

Conclusion

VCUGs are one of the most commonly performed imaging studies in children. They have a low complication rate and provide information on structure and function. Modern techniques and judicial use of radiation have significantly reduced the overall radiation exposure. Although still considered one of the most distressing studies, proper patient preparation and the use of sedation, when needed, can help lower distress levels in both the child and their parents.

Key Points

- When using radiation, the ALARA principle, or *a*s *l*ow *a*s *r*easonably *a*chievable, should be implemented
- Quality assurance measurements should be implemented to assess for appropriate exposure levels in digital imaging
- VCUGs can be safely performed during a urinary tract infection once appropriate antibiotics have been initiated
- Appropriate patient and parental preparation can decrease distress associated with the study. When appropriate, sedation can be used without significantly affecting test results
- Ideally, contrast media should be at body temperature to decrease patient distress and inadvertent early detrusor contractions causing the bladder to empty at lower volumes
- Cyclic VCUGs should be performed in children under the age of 5 years, those in whom VUR or ectopic ureters is suspected, and in those with spontaneous voiding at volumes less than expected for age
- Complications are low. Special considerations should be implemented in patients at risk for autonomic hyperreflexia (dysreflexia)

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