Tips and tricks to evaluate the urethra through serial voiding urosonography (VUS): making it easy.

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Learning objectives

- To provide tips and tricks for obtaining a voiding study of the urethra with high image quality in nearly 100% of patients.

- To reaffirm the ease of observing the morphology and function of the urethra by urosonography.

Background

Serial voiding urosonography (VUS) is a dynamic test that consists of the evaluation of the urinary tract by introducing an ultrasound contrast agent into the bladder. At first, VUS was indicated only for the study of vesicoureteral reflux (VUR) in girls or for the follow-up of VUR in both sexes, because it was thought that VUS did not allow for the correct evaluation of the male urethra. A few years later, in part due to technological advances, it was demonstrated that the urethra was not a limitation of the technique. The latest European guidelines for the use of ultrasound contrast agents (The EFSUMB Guidelines and recommendations on the clinical practice of contrast enhanced ultrasound, update 2011) recognize that VUS enables the study of the urethra. Several recent papers show that transperineal US during voiding allows reliable assessment of urethral pathology. Thus, one of the early restrictions for VUS has been overcome (ESPR uroradiology task force imaging recommendations in pediatric uroradiology, Pediatric Radiol 2014).

Voiding cystourethrography (VCUG), to date the gold standard for the study of the urethra, enables the correct evaluation of the urethra in 93% of patients (Kassa Dargue). However, in our 9 years’ experience with VUS including 1862 patients aged 0 to 16 years, we have been able to evaluate the urethra correctly in 98.7%. Here we describe the technique we use and provide some tips and tricks to help ensure it is done right and thus increase its reliability in the study of the urethra.

Findings and procedure details

PREPARATION
Requirements for the technique

1. Material

a. High-end ultrasound scanner with dedicated software for contrast-enhanced studies. With second-generation contrast agents it is recommended to use a particular harmonic imaging mode based on pulse inversion with a low mechanical index (MI) (0.09-0.16). This software also enables color coding of the conventional B-mode signal to improve image resolution and enable dual image display (basic image and harmonic image) on a single screen Fig. 1 on page 9. The harmonic images make it easier to perform the procedure, because a single probe can be used to study the entire urinary tract. We currently use different types of probes: a 9 MHz linear probe for newborns and infants and a convex multifrequency (6 - 4 MHz) probe for children. A high frequency (10 - 14 MHz) linear probe can also be used when greater anatomic detail is necessary for the anterior urethra.

b. Contrast agent: We currently use (off label) the second-generation ultrasound contrast agent SonoVue® (Bracco, Milan, Italy), which consists of sulfur hexafluoride stabilized with various surfactants (phospholipids and palmitic acid). The dose is 1 ml of the standard solution; a vial of ultrasound contrast agent preparation contains 5 ml and is good for 6 h; thus, one vial enables five studies to be done in different patients, and this helps to keep costs down (provided that local laws allow shared use of medication).

c. A 5F or 8F hydrophilic catheter.

d. Saline solution 0.9% (500 ml bag) at room temperature with an IV drip line.

e. Pressurization device (sphygmomanometer).

f. Others: Bandages, iodine, etc. Fig. 2 on page 9

1. Personnel:

a. Two technologists.

b. One radiologist.

Procedure before the test:
a. Provide parents with detailed information about the test and obtain written informed consent.

b. Provide antibiotic prophylaxis in function of the patient's history and clinical context.

**Carrying out the test:**

- No sedation is required. Give the patient an age-appropriate explanation.
- Prepare the contrast material following the manufacturer's instructions.

1. Insert a 5F or 8F hydrophilic catheter and empty the bladder completely.

2. Connect the catheter to a venous infusion line connected to a plastic bag containing 500 ml of 0.9% saline solution at body temperature placed on the examination table.

3. Place the bag of saline solution in the cuff of the sphygmomanometer (after preparing all the material).

4. Inject 1 ml contrast agent into the bag of saline solution and shake to homogenize the contents Fig. 3 on page 10. Use the sphygmomanometer to apply a sustained pressure of 90mmHg (the equivalent of a 100 cm column of water, corresponding to a high perfusion study) to the bag of saline solution. Fig. 4 on page 11. This results in a gentle, constant flow of the contents, ensuring the correct mixture of contrast agent and saline solution and thus avoiding the accumulation of contrast material in the anterior aspect of the bladder, which could cause an acoustic shadow that would impede the correct study of the bladder due to the difficulty of dissolving the contrast agent with its greater molecular weight.

5. To ensure a successful VUS study, the radiologist takes control of the ultrasound scanner and the two technologists are in charge of the intravesical administration of the contrast material at high pressure and of immobilizing the patient and controlling the urinary catheter. Fig. 5 on page 12

**Imaging procedure.**

1. Study of the bladder filling phase to evaluate bladder capacity and morphology and to detect disease.
Within seconds of the start of bladder filling with a suprapubic approach, we observe the contrast material being progressively and homogeneously incorporated, bringing about generalized distention or filling of the bladder. The bladder is well defined by a thin hypoechoic band that corresponds to the bladder wall, and the normal detrusor muscle is seen in the posteroinferior aspect Fig. 6 on page 13. During the filling phase, we intermittently check to make sure that the bubbles are not breaking up or that the contrast material is not losing its intensity Fig. 7 on page 14. When we observe correct filling, it generally coincides with clinical symptoms such as crying and/or flexion of the toes; at this point, we consider that we have reached the maximum capacity of the bladder, and we acquire images in the transverse and sagittal planes of the bladder and calculate its volume. We have observed that there is a good correlation between the volume achieved and the capacity of the bladder as classically calculated in pediatric radiology (Caffey) using the formula (vol.=(age + 2 x 30 ml) in children older than one year Fig. 8 on page 15.


To evaluate the urethra, we use a transperineal approach, placing the probe in the sagittal plane in all boys, regardless of age, and we can also use a suprapubic approach in infants. A transpelvic approach is used for the study of the urethra in girls (i.e., placing the convex transducer sagittally against the suprapubic area of the abdominal wall; in some girls (older girls), a longitudinal interlabial approach is used.

a. **With a transurethral catheter.**

A tip for starting to obtain experience in the correct study of the urethra is to start to view the transurethral catheter in the sagittal plane with a transperineal approach during filling: this enables you to obtain a complete sagittal slice of the entire urethra and bladder. Fig. 9 on page 16.

In all infants and children, we systematically use what is known as a *cyclic study (double filling and double voiding of the bladder)*. This approach was first used to evaluate the reliability of VCUG (AJR 1989 Jequier S) and later to increase the detection of VUR (Radiology 1992 Paltiel H). In infants, it is recommended to leave the catheter in place.

Cyclic studies are easy to do because, on the one hand, the intravesical catheter is loosely fixed to the skin with adhesive tape, and on the other hand, its caliber is about one-third that of the urethra, so the patient can spontaneously void around the catheter at any point in the study. Fig. 10 on page 17.
Using a 500 ml bag of saline solution and this technique, the bladder can be refilled several times while maintaining the same signal quality from the contrast material.

b. Without a catheter.

In our experience, if the child voids around the catheter, it minimizes the discomfort of the start of spontaneous voiding (secondary to manipulation) that is achieved in slowly withdrawing the catheter, thus making it easier to achieve continuous voiding.

In patients in whom withdrawing the catheter does not immediately achieve voiding, we use other, classical tricks like gentle provocation by running a nearby faucet or dribbling lukewarm water on the perineum). Fig. 11 on page 18.

The urethra is considered normal when we see adequate distention and normal caliber along its entire length, with continuous progression of contrast material toward the exterior during voiding (Berrocal). As reference values for the distention during voiding, we use 6.4 ± 0.78 mm (range 4.0 - 9.2 mm) for the posterior urethra and 5.8 ± 0.91mm (range 3.3 - 8.9 mm) for the anterior urethra. The difference in the caliber of the posterior and anterior urethra is between 0 and 2 mm. For the female urethra, we use 9.5 ± 1.1 mm (range 4.0 - 9.0 mm) Fig. 12 on page 19 as the reference value. Urethrovaginal reflux, considered physiological, is often seen. Fig. 13 on page 20, Fig. 14 on page 21, Fig. 15 on page 22.

3. Dynamic study of the bladder / urethra during voiding (without a catheter)

The suprapubic transpelvic approach to the male urethra during urgent voiding guarantees the evaluation of the urethra without the need to move the probe to the perineal region and thus avoids the loss of information. Fig. 16 on page 23.

Continuous images of voiding can be obtained in real time. Fig. 17 on page 24

Lastly, we evaluate the residual urine and the urethra after voiding.

4. Simultaneous renal study to detect reflux.

Simultaneously during the filling phase and voiding through the catheter, we study the kidneys by alternating between longitudinal and cross-sectional slices with the patient in
the supine position. In the renal study, we are especially careful to detect VUR, defined as the presence of microbubbles of contrast material in the pyelocalyceal system and ureters. To grade VUR, we use the five-level grading system adapted to VUS (Kassa 9) or the international reflux grading system.

The entire study (from the time the patient is admitted to the examination room until the end of the test) does not differ from that necessary for VCUG (25 - 30 minutes).

**Image acquisition**

We use a dedicated program to obtain images of the entire urinary tract by adjusting the segmental B-mode gain and the general gain for the harmonic image. Trick: Gain should be adjusted so that in dual mode the habitual hyperechoic signal of the renal hilum is canceled in the contrast-specific mode until it is reduced to the absolute minimum (screen practically black).

Ideally, images of the urethra should be obtained in the anatomic direction (as in VCUG); however, although this is technically possible, it has its limitations. VUS is a fast, dynamic technique to evaluate the entire urinary tract. The problem is that when you change the image to evaluate the urethra in the anatomic direction, you also change the direction for evaluating the kidneys, so you waste time because you have to keep changing directions every time you want to evaluate a different element along the urinary tract. Fig. 18 on page 25

During the tests, minimal sequential static images of the urethra are acquired (apart from those acquired for the rest of the urinary tract). Fig. 19 on page 26

1. Images of the bladder at the start and after total filling (volume calculation).
2. Transperineal image with the catheter in place during filling (optional).
3. Urethra with the transurethral catheter and voiding around the catheter.
4. Urethra during voiding before the catheter is withdrawn: serial (dynamic) images or videos are acquired during voiding.
5. Residual urine in the bladder.

Optional: If urgent uncontrollable voiding occurs or if significant residue remains, we use a suprapubic transpelvic sagittal approach (in infants) to ensure a correct study of the morphology of the urethra and to evaluate voiding in real time. Fig. 20 on page 27, Fig. 21 on page 28, Fig. 22 on page 29, Table 1 on page 30.
CASES WHERE WE WERE UNABLE TO SEE THE URETHRA

From July 2005 through December 2014, we did 1862 VUS in boys and girls; we were unable to see the urethra in 24.

- In 7 cases, the bubbles broke before the end of the study, probably because the probe was placed over the bladder for too long, so it is better to view bladder filling intermittently. In some of these children, the catheter had already been withdrawn and we decided not to recatheterize the urethra. If the catheter had not been withdrawn, introducing more contrast material would have made it possible to finish the study successfully.

- In 11 boys (1 one-year-old, 1 two-year-old, 7 three-to-ten-year-olds, and 2 ten-to-fifteen-year-olds), the urethra was not seen because the patient did not cooperate (no voiding around the catheter and no spontaneous voiding).

- In 3 studies, we did not insist on voiding because the urethra had already been studied on previous VUS.

- In some girls, due to the low prevalence of urethral pathology in girls, the study of the urethra was mistakenly neglected.

Observation

- We were able to study the urethra in all patients < 1 year old.

ADVANTAGES OF VUS

1. The main advantage of this technique is that it does not use ionizing radiation.
2. The ambiance is less hostile for both patients and staff, and this improves the voiding rate.
3. It enables a complete view of the urethra in both sexes.
4. Mixing the contrast material in a bag of physiological saline enables us to do a complete cyclic study and this increases the success rate of the study of the urethra.
5. It increases the number of images acquired.
6. It enables the obtainment of a dynamic morphological study, which improves the evaluation of the urethra.
7. We didn't observe any adverse effects using the second-generation contrast agent.
8. In our experience, it enables the detection of normal variants of the urethra as well as of the most prevalent urethral pathology. Fig. 23 on page 31, Fig. 24 on page 32, Fig. 25 on page 33, Fig. 26 on page 34, Fig. 27 on page 35 Fig. 28 on page 36 Fig. 29 on page 37 Fig. 30 on page 38 Fig. 31 on page 39 Fig. 32 on page 40

Images for this section:

**Fig. 1:** Dual image display (basic image and harmonic image) on a single screen in a transperineal sagittal plane. Bladder (star). Urethra (arrow head)
Fig. 2: Material for VUS with a second-generation ultrasound contrast agent
**Fig. 3:** Trick: Inject 1 ml contrast agent into the bag of saline solution and shake to homogenize the contents.
Technical procedure of VUS with a second-generation ultrasound contrast agent

**Fig. 4:** Trick: Use the sphygmomanometer to apply a sustained pressure of 90mmHg (the equivalent of a 100 cm column of water, corresponding to a high perfusion study) to the bag of saline solution. This results in a gentle, constant flow of the contents, ensuring the correct mixture of contrast agent and saline solution.
Fig. 5: TIP: To ensure a successful VUS study, the radiologist takes control of the ultrasound scanner and the two technologists are in charge of the intravesical administration of the contrast.
Fig. 6: The bladder is well defined by a thin hypoechoic band that corresponds to the bladder wall (star).
**Fig. 7:** Progressively incorporation of the contrast material and generalized distension of the bladder. TIP: During the filling phase, we intermittently check to make sure that the bubbles are not breaking up or that the contrast agent is not losing its intensity.
Fig. 8: We have observed that there is a good correlation between the volume achieved and the capacity of the bladder as classically calculated in pediatric radiology (Caffey) using the formula \( \text{vol.} = (\text{age} + 2 \times 30 \text{ ml}) \) in children older than one year. TIP: When we observe correct filling, it generally coincides with clinical symptoms such as crying and/or flexion of the toes; at this point, we consider that we have reached the maximum capacity of the bladder. Ej: A 1 year and 6 months old girl. Using the formula corresponds to a volume of 90cc, in the example we had a complete bladder repletion with 98cc
**Fig. 9:** A tip for starting to obtain experience in the correct study of the urethra is to start to view the transurethral catheter in the sagittal plane with a transperineal approach during filling: this enables you to obtain a complete sagittal slice of the entire urethra and bladder. The notch (arrow) corresponds to the external sphincter in a sagittal-oblique plane.
Fig. 10: Sagittal plane suprapubic where we observe voiding around the catheter (star)
Fig. 11: In our experience, if the child voids around the catheter (arrow head), it minimizes the discomfort of the start of spontaneous voiding (secondary to manipulation) that is achieved in slowly withdrawing the catheter, thus making it easier to achieve continuous voiding. In patients in whom withdrawing the catheter does not immediately achieve voiding, we use other, classical tricks like gentle provocation by running a nearby faucet or dribbling lukewarm water on the perineum).
The mean distention of the urethra during voiding:

- Posterior Urethra: 6.4/0.78 mm (range 4.0-9.2mm)
- Anterior Urethra: 5.8/0.91 mm (range 3.3-8.9 mm)

The difference in calibre between the posterior and anterior urethras range between 0 and 2 mm.

**Fig. 12:** The urethra is considered normal at voiding US when adequate distention and a homogeneous calibre of the whole urethra, as well as continuous progression of the contrast material.
Normal Variants: Physiological urethrovaginal reflux

The mean urethra distension: 5.9/1.1 mm and (range 4.0-9.0 mm)

Fig. 13: U: Uterus. V: Vagina. B: Bladder.
Fig. 14: Transitory decrease in the caliber of the bulbar urethra and a slight dilatation of the PU (never more than 9 mm). This finding is more evident in VUS than VCUG because VUS can achieve a strict sagittal image of the urethra.
Fig. 15: The visualization of extraluminal contrast in the proximal part of the prostatic urethra, which in a oblique view is demonstrated bilaterally, suggests the diagnosis of reflux to the prostatic ducts. This finding has a very good correlation with images from VCUG showing this entity.
Fig. 16: The suprapubic transpelvic approach to the male urethra during urgent voiding guarantees the evaluation of the urethra without the need to move the probe to the perineal region and thus avoids the loss of information.
This final study without the catheter is the most important to assess the urethra.

Fig. 17: This final study without the catheter is the most important to assess the urethra.
Fig. 18: Ideally, images of the urethra should be obtained in the anatomic direction (as in VCUG); however, although this is technically possible, it has its limitations.
Fig. 19: 1. Images of the bladder at the start and after total filling 2. Volume calculation. 3. Transperineal image with the catheter in place during filling (optional). 4. Urethra with the transurethral catheter and voiding around the catheter. The catheter is identified in the membranous portion of the urethra (stars). 5. Urethra during voiding before the catheter is withdrawn: serial (dynamic) images or videos are acquired during voiding. Residual urine in the bladder.
Fig. 20: Sequential study (including the upper urinary tract) in an 8-year-old boy with a history of (a) right ectopic multicystic dysplastic kidney disease. In the postnatal study, cystic lesions were also detected in the seminal vesicles. (b) Transverse slice of the bladder and seminal vesicles. (c) Sagittal slice shows the bladder and urethra. Cystic lesions of the seminal vesicles can be associated with multicystic kidney disease (Riccabona M.). (d). Normal left kidney.
Fig. 21: VOIDING UROSONOGRAPHY to rule out reflux in the left kidney and seminal vesicles. (a). Bladder in the initial filling phase (b). and (c). Grade III vesicoureteral reflux of the left kidney. (d). and (e). Calculation of the capacity in the sagittal and transverse planes. (f). and (g). Transperineal sagittal plane, entry of contrast through the transurethral catheter.
Fig. 22: (A). Sequential study of spontaneous voiding prior to the withdrawal of the catheter (Images obtained using a sagittal transperineal approach). (B). Postvoiding residue without reflux into the vesicle. (C). Real-time study (suprapubic sagittal approach) of residual voiding.
Table 1: Summary
Fig. 23: Characteristic morphological changes (thickening and irregularity of the bladder wall and diverticula, dilatation of the posterior urethra, decreased caliber of the anterior urethra, difficulty in the progression of contrast material through the valvular area) compared with a normal urethra.
**Fig. 24:** Extravasation of contrast material caused by a ruptured diverticulum in the anterior urethra (asterisks).
**Fig. 25:** Abrupt change in urethral caliber at the level of the bulb (arrow).
Fig. 26: Decreased caliber of the bulbar urethra with a prestenotic dilation.
**Fig. 27:** Dilation and reflux of contrast material to a diverticulum in the prostatic utricle (star).
Fig. 28: Intravesical filling defect corresponding to a ureterocele (star) that does not prolapse into the urethra during voiding.
Fig. 29: (a). Ectopic intravesical ureterocele. (b). and (c). On voiding, it prolapses to the posterior aspect of the neck of the bladder, resulting in an evident dilation and an indentation in the internal sphincter.
**Fig. 30:** Compound image of a duplicated kidney with grade V reflux to the inferior system and an ectopic ureterocele prolapsing into the urethra (star).
**Fig. 31:** Good correlation between VCUG and VUS.
**Fig. 32:** A 6-year-old girl with daytime wetting, urethra dilation suggestive of vesical dysfunction.
Conclusion

Using these tricks and tips for VUS, it possible to obtain better results for imaging studies of the urethra than what has been reported for VCUG. These improvements result from the technique itself, which makes it possible to work in a radiation-free environment that is more comfortable and allows us to get closer to patients (allowing us to interact with them more to distract them with toys, for example), which in turn facilitates cooperation during the test. On the other hand, this VUS protocol lets us use techniques to stimulate voiding.

In our opinion, various aspects that continue to be considered limitations of VUS, including the off-label use of the contrast agent (common practice in pediatrics), urinary catheterization (common practice in pediatric emergencies), or the cost of the test (which can be reduced by using one vial for several patients, if local laws allow it), should not impede the generalized used of the technique.

We expect that the guidelines will indicate VUS as the technique of choice for the study of VUR and of the entire urinary tract including the urethra in both sexes.

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References


