Point-of-Care Ultrasound to Assess Anuria in Children

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Abstract: Anuria in children may arise from a host of causes and is a frequent concern in the emergency department. This review focuses on differentiating common causes of obstructive and nonobstructive anuria and the role of point-of-care ultrasound in this evaluation. We discuss some indications and basic techniques for bedside ultrasound imaging of the urinary system.

Key Words: point-of-care ultrasound, anuria, imaging, evaluation, diagnosis

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TARGET AUDIENCE

This article is intended for health care providers who see children and adolescents in acute care settings. Pediatric emergency medicine providers, emergency medicine providers, and those working in acute care pediatric offices and urgent centers may have particular interest in this article.

LEARNING OBJECTIVES

After completion of this article, the reader should be able to:

1. Identify common etiologies of obstructive and nonobstructive anuria in children.
2. Identify the key points in ultrasound (US) differentiation between obstructive and nonobstructive anuria.
3. Describe techniques for performing point-of-care US evaluation of the pediatric urinary collecting system to identify obstruction.

Children presenting with a history or chief complaint of anuria are a common challenge for the clinician. The differential diagnosis is diverse, spanning causes from dehydration or urinary retention to urinary tract obstruction or kidney failure. In some cases, the history and physical examination may be clear enough to direct care and avoid unnecessary testing. In other cases, however, point-of-care US can be useful to quickly and easily guide further testing and treatment.

The kidney and bladder are sonographically accessible and recognizable even by those new to US. Thus, the urinary tract can be a useful starting point in learning and teaching ultrasonography in the acute care setting.1

A recent policy statement2 by the American Academy of Pediatrics endorses the use of point-of-care US in the pediatric emergency department: “Ultimately, this will improve the care of pediatric patients. ... As much as it is our responsibility to understand the limitations and challenges associated with integrating point-of-care US into pediatrics, it is our responsibility to our patients to stay abreast of the most current advances in medicine and provide the safest, most efficient, state-of-the-art care. Point-of-care US can help us meet this goal.”

CLINICAL CONSIDERATIONS

In some cases, as for example with obvious dehydration or known renal failure, anuria is not mysterious, and evaluation can be directed without imaging. In many other cases, however, point-of-care US can be a simple and helpful way to assess urine volume, differentiate urinary retention in the bladder from other causes, evaluate other pathology, and, detect obstructive causes. When should point-of-care US be performed? Because this imaging is low-risk, and rapid, early use is encouraged in any case where it might be helpful. Scanning the bladder first answers the key question of whether urine is present. When a urine sample is sought, an empty bladder may suggest rehydration before either attempted voiding or, if indicated, catheterization. If, on the other hand, an overdistended bladder, hydronephrotic kidney, or hydroureter are seen, alone or in combination, this can quickly guide management to more definitive imaging or consultation, avoiding delay and unneeded testing and treatment.

Artifactual or apparent anuria may arise from several causes in a child who is actually voiding; this is common when diarrhea obscures the presence of urine in diapers, when another caretaker changes a wet diaper without a parent’s awareness, or when a young child gives a misleading verbal report. Scant but adequate urination can be missed when modern superabsorbent diapers appear misleadingly dry. In a well-appearing child, the finding of a normal volume of urine in the bladder on US may confirm that kidney function, hydration, and voiding do not need further investigation.

An especially common cause of urinary retention in children is dysuria leading to voluntary urine withholding, bladder distention, more dysuria, and a cycle of pain and anuria. This sequence may be suggested in cases where a history or suspicion of dysuria accompanies abdominal pain or a palpable bladder. Typical scenarios in children include not only urinary tract infection, but also straddle injury or vulvovaginitis in girls, meitis or minor penile trauma in boys, recent catheterization or urologic procedures, constipation with painful stool retention, and others.

In cases of suspected voluntary retention leading to bladder neck contractions, US confirmation of bladder distention and quantification of bladder volume may be sufficient to direct appropriate care. If recent catheterization or instrumentation is the cause, common sense suggests possible urologic consultation and a reasonable, sometimes prolonged, period of waiting for spontaneous voiding in order to avoid renewing a cycle of pain and withholding. If, however, bladder distention is causing severe pain, especially in suspected cases of simple inflammation, infection, or minor injury, one-time catheterization may be helpful.

In these cases, the authors have sometimes achieved good results by passing a small straight urinary catheter lubricated with 2% viscous xylocaine to relieve bladder distention (the xylocaine does not notably reduce the initial pain of catheterization, but is intended to lessen subsequent dysuria and avoid a repeated cycle of urinary retention). The volume of total urinary drainage should be noted. The urine should be sent for urinalysis and for culture if indicated.
In some cases of urinary retention, point-of-care US may also suggest evidence for a suspected cause of dysuria, as for example, bladder wall thickening in cystitis.

In any case of bladder distention, point-of-care US of the ureters and kidneys is suggested. Importantly, the presence of hydronephrosis or hydroureter or both suggests that bladder distention is not acute. Urologic consultation may be helpful and is also suggested if catheterization is contraindicated or unsuccessful.

Less common causes of urine retention in children may include neurologic emergencies (eg, spinal cord dysfunction) as well as medication side effects or toxicity.

In many cases, quantification of bladder volume is helpful (Fig. 1). Measurement of bladder wall thickness can also be revealing. Table 1 contains examples of formulas and normal values for these measurements.

Even when bladder volume is the chief question, experts suggest US screening of the kidneys and ureters. This additional examination takes little time and may discover important associated findings, such as upper tract distention in cases of vesicoureteral reflux. It may also reveal incidental findings that affect care, such as preexisting hydronephrosis or polycystic kidney. Although upper tract obstruction can cause anuria with a single kidney or collecting system, a detailed discussion of the causes and US findings of upper tract abnormalities is beyond the scope of this review. Interested readers are referred to more general reviews.1,7-9

In cases of anuria or abnormal voiding, point-of-care US may suggest an obstructive cause of anuria and localize the problem, guiding further evaluation and management. Urinary tract obstruction is often readily reversible, but if unrecognized may lead to complications from urinary tract infection to urosepsis, or from renal injury to end-stage renal disease.

Obstruction can occur anywhere along the urinary tract. Common causes in children include ureteropelvic junction obstruction, scarring from urinary tract infection, urolithiasis or nephrolithiasis, bladder distortion due to rectal distention, and (in males) posterior urethral valves. Less common causes may range from a gravid uterus to cancer.

Imaging is the usual preferred means of assessing for urinary obstruction, and US is often the first modality of choice. Point-of-care US will suggest the relative level of the obstruction, distinguishing distention of the bladder from that of the ureter or kidney.

If obstruction is suggested by point-of-care US, further imaging and documentation may follow. Computed tomography may be indicated, for example, in patients with acute flank pain and suspected nephrolithiasis, or where visualization of the ureters is required.10

Specific Scenarios

Beyond the common questions of artifactual anuria, possible dehydration, or suspected urinary retention, other presentations

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**TABLE 1. Bladder Measurements, Calculation, and Normal Values**

<table>
<thead>
<tr>
<th>Calculated Bladder Volume*</th>
</tr>
</thead>
</table>
| Length (front to back) × width x height × 0.53 | 3
| Estimated normal bladder capacity in children² |
| (Age in years + 2) × 30 mL⁴ | 5
| Normal bladder wall thickness (lateral or anterior wall), child⁵ |
| Full bladder: ≤ 2.7 mm | 6
| Empty bladder: ≤ 3.9 mm | 6

*Many ultrasound devices have built-in algorithms for volume calculation.

²Many other formulas are also used. Due to variability in calculation, bladder shape, and measurement, volume estimates may vary by as much as 13% to 35% or more.

³In adults, the normal full bladder contains approximately 300 to 400 mL but may at times be as large as 1000 mL. The urge to void is typically felt at volumes between 150 and 400 mL.

⁴Adult norms are approximately 1 mm greater than these values.
may also suggest the utility of point-of-care US examination of the urinary tract.

In some cases of urinary retention, anuria is less obvious than abdominal pain. Point-of-care US may be helpful when it reveals or confirms bladder distention in these cases, and especially when this finding leads on to later voiding (or, if necessary, catheterization) with relief of pain.

Likewise, a midline abdominal mass will sometimes turn out to be an unexpectedly large bladder, especially in nonverbal children. Point-of-care US also has an obvious role in quantifying bladder volume in children who lack bladder sensation (eg, with spina bifida or other neurologic dysfunction) when mass, anuria, incomplete voiding, or overflow incontinence are at issue. Prevoiding and postvoiding examinations can be of obvious utility to examine incomplete bladder emptying.

Posterior urethral valves, unique to boys, are usually now diagnosed by prenatal US, but such imaging is neither universally available nor 100% sensitive. Delayed presentation may be seen in the newborn period or even later childhood with features ranging from an unexplained mass to painful or dysfunctional voiding or even renal failure or hypertension. The definitive study, a voiding cystourethrogram, may be indicated in boys with unexplained bladder distention, bladder wall thickening, and hydrenephrosis.

With anuria after forceful abdominal, pelvic or perineal trauma in boys, it is important to note that urethral tears or transections are not typically revealed by point-of-care US. In such cases, a retrograde urethrogram is the study of choice.

Abdominal trauma in general goes beyond a review of simple anuria. The focused assessment with sonography in trauma (FAST) examination is detailed in standard sources. In the presence of free fluid on FAST imaging, urinary system trauma is one of several important considerations. Possible injuries can include renal laceration, ureteral perforation, or bladder rupture. Depending on the patient's hemodynamic stability, a positive FAST scan in this setting may lead to consideration of exploratory laparotomy or to further evaluation by computed tomography.

**URINARY TRACT US**

**Techniques and Training**

Ultrasound imaging is highly operator-dependent, and providers will want to have basic training and experience in setting up and operating an US device, in orienting and moving the probe to acquire good images, and in image interpretation.

**Timing**

Although early US will be indicated in many pediatric scenarios, such as potential dehydration or urinary retention, more detailed kidney and ureter examination may at times be achieved by repeat examination after assuring adequate hydration and a full bladder.

**US Probe Choice and Orientation**

A curvilinear US probe gives the best detail except in some infants and very small children, where a linear probe may be useful. The marker or orientation indicator on the curvilinear probe is usually placed to the patient's right side for transverse scanning and toward the patient's head for sagittal imaging.

**Patient Positioning and Sequence of Examination**

For simple US screening, only supine positioning is needed. The bladder, kidneys, and ureters can be assessed in this position. The examiner first scans the bladder, then the right flank, and then the left flank to visualize the bladder, kidneys, and ureters.

**Bladder Examination**

The pelvic window extends basically from the pubis to the umbilicus. As seen in Figure 1, the transverse plane is examined...
first to identify the bladder and measure width and front-to-back length; the sagittal plane is then examined and height is measured. Lateral or anterior wall thickness should also be noted and measured (Fig. 2); the posterior wall is subject to artifact.\textsuperscript{13} Table 1 addresses these measurements and calculations.

The presence of bilateral or unilateral hydrourerter behind the bladder can be detected on the transverse view (Fig. 3). Free fluid may be most easily seen in the sagittal view.

**Kidney and Ureter Examination**

After scanning the bladder, the examiner places the curvilinear probe laterally in the right flank approximately in the midaxillary line. With the probe indicator toward the patient's head, one scans and sweeps superiorly and inferiorly as well as anteriorly and posteriorly to find and outline the kidney. Recognition of the liver will aid orientation and help localize the kidney (Fig. 4). While being sure to visualize all structures from the superior to inferior pole, the size of the kidney should be assessed and recorded. Table 2 gives an example of normal value calculation for kidney length in children according to age. Hydronephrosis or hydrourerter may also be detected in renal views.

The kidney should then be evaluated in the transverse orientation with the probe indicator toward the patient's right side. Because the right upper quadrant is the most dependent portion of the peritoneum, special attention should be directed to the presence of any free fluid.

After assessment of the right kidney, one proceeds to the left flank, again with the probe indicator toward the patient's head. Here too, a recognizable landmark such as the spleen may be sought (Fig. 5). Evaluation of the left kidney follows the same sequence as that for the right kidney.

**TABLE 2.** Formulas to Calculate Normal Values (in Centimeters) for Kidney Length in Children\textsuperscript{*}\textsuperscript{14,15}

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;12 months</td>
<td>$4.98 + (0.155 \times \text{age in months})$</td>
</tr>
<tr>
<td>12 months+</td>
<td>$6.79 + (0.22 \times \text{age in years})$</td>
</tr>
</tbody>
</table>

*These are examples; a number of norms and formulas exist.

**Advanced Examination**

Providers familiar with color Doppler US may be able to image the trigone region of the bladder for bilateral ureteral jet flow into the bladder, which helps rule out a complete more proximal obstruction. This is done with the probe over the base of the bladder and trigone area. Note that it may take several minutes for each ureter to empty into the bladder. Other techniques used to assess the kidneys and great vessels are beyond the scope of this review.\textsuperscript{8,9,16,17}

**SUMMARY**

Although the cause of pediatric anuria may at times be clear after a careful history and physical examination, point-of-care US is a safe and easy way to gain additional data, refine the differential diagnosis, and direct management. Point-of-care US has limitations and is operator dependent, but given that the kidney and bladder are among the most sonographically accessible organs, it is within the reach of many users and may provide a useful starting point for further training.

**REFERENCES**


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CME EXAMINATION

August 2016

Please mark your answers on the ANSWER SHEET.

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1. A 9-month-old girl with a 24-hour history of fever, vomiting, and diarrhea presents because parents have noted no urine output in 12 hours. Bedside ultrasound of the bladder reveals 50 ml of urine. Parents should be told:
   a. It is impossible to assess hydration, because we don’t know when the child last voided.
   b. Given this low volume of urine, the child is likely dehydrated.
   c. The child is probably normally hydrated, since urine can be missed in with diarrhea in diapers.
   d. The ultrasound results suggest a likely urinary tract infection.
   e. The child likely has voluntary urinary retention, so catheterization is indicated.

2. A 12-month-old boy presents with an abdominal mass noted below the umbilicus. Parents say the child has been fussy and has not voided today. A distended bladder is seen on ultrasound. Which of the following most strongly suggests chronic urinary retention?
   a. The presence of fever, dysuria, and hematuria
   b. A large mass of hard stool noted on rectal examination
   c. A history of prior urinary tract infection
   d. The presence of hydronephrosis on ultrasound
   e. The presence of bladder wall thickening on ultrasound

3. A 2-year-old girl has anuria after a straddle injury sustained by falling on a plastic toy. Examination shows only superficial laceration to the labia minora. She is unable to void after a further hour’s observation. Which of the following statements best describes the role of point-of-care ultrasound?
   a. Ultrasound imaging of the bladder, ureters, and kidneys is indicated.
   b. Ultrasound imaging should be limited to simple measurement of bladder volume.
   c. Ultrasound imaging should be performed after bladder catheterization to ensure complete emptying.
   d. Ultrasound imaging should be performed using the techniques of the FAST examination.
   e. In this setting, ultrasound should be avoided in favor of a voiding cystourethrogram.

4. Which of the following is a true statement regarding techniques for point-of-care ultrasound?
   a. Prone positioning is required to visualize the kidneys.
   b. A curvilinear probe is preferred except in very small children.
   c. Ultrasound measurement of distance is unreliable.
   d. Hydronephrosis cannot be detected on bladder ultrasound views.
   e. Color Doppler techniques are required to detect obstruction.
ANSWER SHEET FOR THE PEDIATRIC EMERGENCY CARE
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August 2016

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Name (please print): ___________________________________________________________________________________________
Street Address _______________________________________________________________________________________________
City/State/Zip _______________________________________________________________________________________________
Daytime Phone ______________________________________________________________________________________________
Specialty ___________________________________________________________________________________________________

Your completion of this activity includes evaluating them. Please respond to the following questions below.

Please rate this activity (1 - minimally, 5 - completely)
Was effective in meeting the educational objectives
Was appropriately evidence-based
Was relevant to my practice

Please rate your ability to achieve the following objectives, both before this activity and after it:
1 (minimally) to 5 (completely)

1. Identify common etiologies of obstructive and nonobstructive anuria in children.
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How many of your patients are likely to be impacted by what you learned from these activities?

○ <20% ○ 20%–40% ○ 40%–60% ○ 60%–80% ○ >80%

Do you expect that these activities will help you improve your skill or judgment within the next 6 months? (1 - definitely will not change, 5 - definitely will change)

How will you apply what you learned from these activities (mark all that apply):

In diagnosing patients
In monitoring patients
In educating students and colleagues
As part of a quality or performance improvement project
For maintenance of board certification
To consider enrolling patients in clinical trials

Other

Please list at least one strategy you learned from this activity that you will apply in practice:

How committed are you to applying these activities to your practice in the ways you indicated above? (1 - minimally, 5 - completely)

Did you perceive any bias for or against any commercial products or devices?

If yes, please explain:

How long did it take you to complete these activities? _______ hours _______ minutes

What are your biggest clinical challenges related to pediatric emergency care?

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