

**American College of Radiology  
ACR Appropriateness Criteria®  
Antenatal Hydronephrosis–Infant**

**Variant 1:                    Antenatal diagnosis of hydronephrosis. Initial neonatal imaging.**

| Procedure   | Appropriateness Category | Relative Radiation Level |
|---|--------------------------|--------------------------|
| US kidneys and bladder retroperitoneal              | Usually Appropriate      | ○                        |
| Voiding urosonography                               | Usually Not Appropriate  | ○                        |
| Fluoroscopy voiding cystourethrography              | Usually Not Appropriate  | ☢☢                       |
| MRI abdomen and pelvis with IV contrast             | Usually Not Appropriate  | ○                        |
| MRI abdomen and pelvis without and with IV contrast | Usually Not Appropriate  | ○                        |
| MRI abdomen and pelvis without IV contrast          | Usually Not Appropriate  | ○                        |
| DTPA renal scan                                     | Usually Not Appropriate  | ☢☢☢                      |
| MAG3 renal scan                                     | Usually Not Appropriate  | ☢☢☢                      |
| Nuclear medicine cystography                        | Usually Not Appropriate  | ☢☢                       |

**Variant 2:                    Antenatal diagnosis of hydronephrosis with normal neonatal ultrasound.**

| Procedure  | Appropriateness Category | Relative Radiation Level |
|--|--------------------------|--------------------------|
| US kidneys and bladder retroperitoneal follow-up in 1-6 months | Usually Appropriate      | ○                        |
| Voiding urosonography  | Usually Not Appropriate  | ○                        |
| Fluoroscopy voiding cystourethrography                         | Usually Not Appropriate  | ☢☢                       |
| MRI abdomen and pelvis with IV contrast                        | Usually Not Appropriate  | ○                        |
| MRI abdomen and pelvis without and with IV contrast            | Usually Not Appropriate  | ○                        |
| MRI abdomen and pelvis without IV contrast                     | Usually Not Appropriate  | ○                        |
| DTPA renal scan  | Usually Not Appropriate  | ☢☢☢                      |
| MAG3 renal scan  | Usually Not Appropriate  | ☢☢☢                      |
| Nuclear medicine cystography                                   | Usually Not Appropriate  | ☢☢                       |

**Variant 3:                    Antenatal diagnosis of hydronephrosis with isolated mild (SFU grade 1 and 2 or APRPD less than 15 mm) hydronephrosis on initial neonatal ultrasound.**

| Procedure  | Appropriateness Category | Relative Radiation Level |
|--|--------------------------|--------------------------|
| US kidneys and bladder retroperitoneal follow-up in 1-6 months | Usually Appropriate      | ○                        |
| Voiding urosonography  | May Be Appropriate       | ○                        |
| Fluoroscopy voiding cystourethrography                         | May Be Appropriate       | ☼☼                       |
| MRI abdomen and pelvis with IV contrast                        | Usually Not Appropriate  | ○                        |
| MRI abdomen and pelvis without and with IV contrast            | Usually Not Appropriate  | ○                        |
| MRI abdomen and pelvis without IV contrast                     | Usually Not Appropriate  | ○                        |
| DTPA renal scan  | Usually Not Appropriate  | ☼☼☼                      |
| MAG3 renal scan  | Usually Not Appropriate  | ☼☼☼                      |
| Nuclear medicine cystography                                   | Usually Not Appropriate  | ☼☼                       |

**Variant 4:                    Male. Antenatal diagnosis of hydronephrosis with moderate or severe (SFU grade 3 or 4 or APRPD greater than 15 mm) hydronephrosis on initial neonatal ultrasound, or hydronephrosis associated with parenchymal abnormalities, hydroureter, bladder wall thickening, or posterior urethral dilation.**

| Procedure  | Appropriateness Category | Relative Radiation Level |
|--|--------------------------|--------------------------|
| US kidneys and bladder retroperitoneal follow-up in 1-6 months | Usually Appropriate      | ○                        |
| Fluoroscopy voiding cystourethrography                         | Usually Appropriate      | ☼☼                       |
| MAG3 renal scan  | Usually Appropriate      | ☼☼☼                      |
| Voiding urosonography  | Usually Not Appropriate  | ○                        |
| MRI abdomen and pelvis with IV contrast                        | Usually Not Appropriate  | ○                        |
| MRI abdomen and pelvis without and with IV contrast            | Usually Not Appropriate  | ○                        |
| MRI abdomen and pelvis without IV contrast                     | Usually Not Appropriate  | ○                        |
| DTPA renal scan  | Usually Not Appropriate  | ☼☼☼                      |
| Nuclear medicine cystography                                   | Usually Not Appropriate  | ☼☼                       |

**Variant 5:**

**Female. Antenatal diagnosis of hydronephrosis with moderate or severe (SFU grade 3 or 4 or APRPD greater than 15 mm) hydronephrosis on initial neonatal ultrasound, or hydronephrosis associated with parenchymal abnormalities, hydroureter, bladder wall thickening.**

| Procedure  | Appropriateness Category          | Relative Radiation Level |
|--|-----------------------------------|--------------------------|
| US kidneys and bladder retroperitoneal follow-up in 1-6 months | Usually Appropriate               | ○                        |
| Voiding urosonography  | Usually Appropriate               | ○                        |
| Fluoroscopy voiding cystourethrography                         | Usually Appropriate               | ⊕⊕                       |
| MAG3 renal scan  | Usually Appropriate               | ⊕⊕⊕                      |
| Nuclear medicine cystography                                   | May Be Appropriate (Disagreement) | ⊕⊕                       |
| MRI abdomen and pelvis with IV contrast                        | Usually Not Appropriate           | ○                        |
| MRI abdomen and pelvis without and with IV contrast            | Usually Not Appropriate           | ○                        |
| MRI abdomen and pelvis without IV contrast                     | Usually Not Appropriate           | ○                        |
| DTPA renal scan  | Usually Not Appropriate           | ⊕⊕⊕                      |

**Variant 6:**

**Antenatal diagnosis of hydronephrosis with moderate or severe (SFU grade 3 or 4 or APRPD greater than 15 mm) hydronephrosis on initial neonatal ultrasound and no evidence of reflux on VCUG.**

| Procedure  | Appropriateness Category          | Relative Radiation Level |
|--|-----------------------------------|--------------------------|
| US kidneys and bladder retroperitoneal follow-up in 1-6 months | Usually Appropriate               | ○                        |
| MAG3 renal scan  | Usually Appropriate               | ⊕⊕⊕                      |
| MRI abdomen and pelvis with IV contrast                        | May Be Appropriate (Disagreement) | ○                        |
| MRI abdomen and pelvis without and with IV contrast            | May Be Appropriate                | ○                        |
| DTPA renal scan  | May Be Appropriate                | ⊕⊕⊕                      |
| MRI abdomen and pelvis without IV contrast                     | Usually Not Appropriate           | ○                        |

## ANTENATAL HYDRONEPHROSIS–INFANT

Expert Panel on Pediatric Imaging: Brandon P. Brown, MD, MA<sup>a</sup>; Stephen F. Simoneaux, MD<sup>b</sup>; Jonathan R. Dillman, MD, MSc<sup>c</sup>; Cynthia K. Rigsby, MD<sup>d</sup>; Ramesh S. Iyer, MD, MBA<sup>e</sup>; Adina L. Alazraki, MD<sup>f</sup>; Dianna M. E. Bardo, MD<sup>g</sup>; Sherwin S. Chan, MD, PhD<sup>h</sup>; Tushar Chandra, MD<sup>i</sup>; Scott R. Dorfman, MD<sup>j</sup>; Matthew D. Garber, MD<sup>k</sup>; Michael M. Moore, MD<sup>l</sup>; Jie C. Nguyen, MD, MS<sup>m</sup>; Craig A. Peters, MD<sup>n</sup>; Narendra S. Shet, MD<sup>o</sup>; Alan Siegel, MD, MS<sup>p</sup>; Muhammad Waseem, MD, MS<sup>q</sup>; Boaz Karmazyn, MD.<sup>r</sup>

### Summary of Literature Review

#### **Introduction/Background**

Antenatal hydronephrosis is the most frequent urinary tract anomaly detected on prenatal screening by ultrasonography (US). Antenatal hydronephrosis occurs approximately twice as often in males as in females [1-4]. With an estimated 4 million births per year in the United States, up to 80,000 fetal studies may detect antenatal hydronephrosis. Most antenatal hydronephrosis is transient with little long-term significance [5-8]. Few children with antenatal hydronephrosis, including some with ureteropelvic junction obstruction (UPJO), vesicoureteral reflux (VUR), and primary megaureter will have significant obstruction, develop symptoms or complications, which requires surgical intervention. Some male children will be diagnosed with more serious conditions, such as posterior urethral valves (PUV), which may require intervention. Early detection and treatment of obstructive uropathy is necessary to mitigate the potential morbidity from loss of renal function.

During prenatal evaluation, most antenatal hydronephrosis is mild, and the cause cannot always be determined with certainty. As a result, postnatal evaluation of these children is frequently performed. In an effort to standardize grading of antenatal hydronephrosis, the Society for Fetal Urology (SFU) introduced a five point grading system in 1988, based on degree of pelvic and calyceal dilation and the thickness of the parenchyma overlying the calices [9]. Since its introduction, the SFU grading system has become the most widely used method to grade pediatric hydronephrosis [10]. Subsequently, several alternative classification schemes have also been devised [3,4,11,12]. Adherence to standardized reporting models is not well adopted according to a recent survey of pediatric radiologists [13,14]. In order to increase standardization of reporting and care, a consensus group from many separate organizations recommended adoption of the urinary tract dilation (UTD) classification system which incorporates prenatal and postnatal imaging findings based on: 1) anterior-posterior renal pelvic diameter (APRPD); 2) calyceal dilation with distinction between central and peripheral calyceal dilation postnatally; 3) renal parenchymal thickness; 4) renal parenchymal appearance; 5) bladder abnormalities; and 6) ureteral abnormalities. For antenatal studies, the seventh US finding to report is the quantity of amniotic fluid [3]. This recently proposed grading classification system, as with any system, will require extensive evaluation to assess and confirm its usefulness in predicting clinical outcomes [3].

For the purposes of the current evaluation, degree of hydronephrosis is based on the SFU grading. The SFU system has been in use for a longer period of time and has good inter-rater reliability [3,15,16]. There are studies that have shown increased accuracy of hydronephrosis grading system if APRPD is measured [17,18]. We therefore have included an APRPD of >15 mm on postnatal imaging as a sign of severe hydronephrosis. Over time, the UTD classification system may predominate, but at present, familiarity with the SFU system is more widespread. Inclusion of the APRPD >15 mm conforms to the intermediate- to high-risk urinary tract dilation stratification [3].

---

<sup>a</sup>Riley Hospital for Children and Indiana University School of Medicine, Indianapolis, Indiana. <sup>b</sup>Children's Healthcare of Atlanta and Emory University, Atlanta, Georgia. <sup>c</sup>Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio. <sup>d</sup>Panel Chair, Ann & Robert H. Lurie Children's Hospital of Chicago, Chicago, Illinois. <sup>e</sup>Panel Vice-Chair, Seattle Children's Hospital, Seattle, Washington. <sup>f</sup>Children's Healthcare of Atlanta and Emory University, Atlanta, Georgia. <sup>g</sup>Phoenix Children's Hospital, Phoenix, Arizona. <sup>h</sup>Children's Mercy Hospital, Kansas City, Missouri. <sup>i</sup>Nemours Children's Hospital, Orlando, Florida. <sup>j</sup>Texas Children's Hospital, Houston, Texas. <sup>k</sup>Wolfson Children's Hospital, Jacksonville, Florida; American Academy of Pediatrics. <sup>l</sup>Penn State Health Children's Hospital, Hershey, Pennsylvania. <sup>m</sup>Children's Hospital of Philadelphia, Philadelphia, Pennsylvania. <sup>n</sup>UT Southwestern Medical Center, Dallas, Texas; Society for Pediatric Urology. <sup>o</sup>Children's National Hospital, Washington, District of Columbia. <sup>p</sup>Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire. <sup>q</sup>Lincoln Medical Center, Bronx, New York; American College of Emergency Physicians. <sup>r</sup>Specialty Chair, Riley Hospital for Children Indiana University, Indianapolis, Indiana.

The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through society representation on expert panels. Participation by representatives from collaborating societies on the expert panel does not necessarily imply individual or society endorsement of the final document.

Reprint requests to: [publications@acr.org](mailto:publications@acr.org)

## Initial Imaging Definition

Imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously in which each procedure provides unique clinical information to effectively manage the patient's care).

## Discussion of Procedures by Variant

### Variant 1: Antenatal diagnosis of hydronephrosis. Initial neonatal imaging.

#### US Kidneys and Bladder Retroperitoneal

US in the immediate postnatal period evaluates for the presence and severity of underlying urologic abnormalities and therefore has a role in guiding management [3,6,12,19-25]. Because of the relative low urine production in newborns, initial imaging should be delayed at least 48 to 72 hours after birth [3,26-29]. Exceptions include newborns with severe, bilateral hydronephrosis and bladder abnormalities, oligohydramnios, or situations in which follow-up studies may be difficult to obtain. In these infants, earlier imaging is indicated [20,27,29,30].

#### Fluoroscopic Voiding Cystourethrography

There is controversy regarding whether all children with antenatal hydronephrosis should undergo voiding cystourethrography (VCUG). A meta-analysis by the American Urology Association found that, on average, approximately 16% of neonates and infants with antenatal hydronephrosis will have VUR. The incidence of VUR was independent of degree of antenatal hydronephrosis, and a quarter of these were found to have no hydronephrosis on postnatal US [31]. There is disagreement over whether this VUR is clinically significant and therefore over the need for diagnosis. Some authors advocate VCUG for all infants with antenatal hydronephrosis, to guide treatment with prophylactic antibiotics [20,27,32,33]. However, currently, most authors (including the 2010 SFU consensus statement) recommend against routine VCUG for antenatal hydronephrosis [2,12,29,34,35]. This is largely because the benefit of prophylactic antibiotics in children with urinary tract infection (UTI) has not been clearly demonstrated and remains controversial. Some studies have suggested that prophylactic antibiotics may be beneficial in patients with VUR [36-38]. The efficacy of prophylactic antibiotics in preventing UTIs or renal damage in patients with antenatal hydronephrosis, with or without VUR, is difficult to determine because of variability in methods and results [39]. In addition, most of the VUR spontaneously resolves [40]. One of the potential risks of VCUG is iatrogenic UTI. This was reported in about 2% of VCUG studies performed for evaluation of antenatal hydronephrosis [39].

#### Voiding Urosonography

Multiple recent investigations evaluating real-time contrast-enhanced US techniques have demonstrated a high degree of diagnostic accuracy, and some demonstrated increased sensitivity as compared to fluoroscopic VCUG in the detection of VUR [41-45]. The main potential disadvantage of voiding urosonography is a lower anatomical detail of the bladder and urethra, and therefore it should not be used as the first study for male patients. Therefore, arguments for and against using voiding urosonography are similar to that of VCUG with the exception of male patients.

#### Nuclear Medicine Cystography

Some studies have suggested equal sensitivity for Tc-99m pertechnetate radionuclide cystography and VCUG [46], whereas others have indicated that radionuclide cystography has improved sensitivity for VUR in infants up to 1 year of age [47]. The main disadvantage of radionuclide cystography is that it does not provide anatomical details of the bladder and urethra and therefore should not be used as the first study for male patients. Therefore, arguments for and against using radionuclide cystography are similar to that of VCUG with the exception of male patients.

#### DTPA Renal Scan

There is no relevant literature to support the routine use of Tc-99m diethylenetriamine pentaacetic acid (DTPA) renal scan in the initial postnatal evaluation of antenatal hydronephrosis.

### **MAG3 Renal Scan**

There is no relevant literature to support the routine use of Tc-99m mercaptoacetyltriglycine (MAG3) diuretic renal scan in the initial postnatal evaluation of antenatal hydronephrosis.

### **MRI Abdomen and Pelvis**

There is no relevant literature to support the routine use of MR urography (MRU) in the initial postnatal evaluation of antenatal hydronephrosis.

### **Variant 2: Antenatal diagnosis of hydronephrosis with normal neonatal ultrasound.**

#### **US Kidneys and Bladder Retroperitoneal Follow-Up in 1–6 Months**

Lower urinary production in the immediate postnatal period can mask urinary tract abnormalities. In a study by Aksu et al [26], 45% of initially normal postnatal studies had abnormal findings on repeat imaging, including UPJO, VUR, and ureterovesical junction obstruction. Even with a normal initial postnatal US, follow-up studies are recommended for exclusion of later-developing hydronephrosis [3,30,48]. Given the late presentation of some urinary tract abnormalities, a repeat US is recommended in 1 to 6 months [4,5,49,50].

#### **Fluoroscopic Voiding Cystourethrography**

There is controversy regarding whether all children with antenatal hydronephrosis should undergo VCUG. A meta-analysis by the American Urology Association found that on average, approximately 16% of neonates and infants with antenatal hydronephrosis will have VUR. The incidence of VUR was independent of degree of antenatal hydronephrosis, and a quarter of these were found to have no hydronephrosis on postnatal US [31]. There is disagreement over whether this VUR is clinically significant and therefore over the need for diagnosis. Some authors advocate VCUG for all infants with antenatal hydronephrosis, to guide treatment with prophylactic antibiotics [20,27,32,33]. However, currently, most authors (including the 2010 SFU consensus statement) recommend against routine VCUG for antenatal hydronephrosis [2,12,29,34,35]. This is largely because the benefit of prophylactic antibiotic in children with UTI has not been clearly demonstrated [36]. The efficacy of prophylactic antibiotics in preventing UTIs or renal damage in patients with antenatal hydronephrosis, with or without VUR, is difficult to determine because of variability in methods and results [39]. In addition, most of the VUR spontaneously resolves [40]. One of the potential risks of VCUG is iatrogenic UTI. This was reported in about 2% of VCUG studies performed for evaluation of antenatal hydronephrosis [39].

#### **Voiding Urosonography**

Multiple recent investigations evaluating real-time contrast-enhanced US techniques have demonstrated a high degree of diagnostic accuracy, and some demonstrated increased sensitivity as compared to fluoroscopic VCUG in the detection of VUR [41-45]. The main potential disadvantage of voiding urosonography is a lower anatomical detail of the bladder and urethra, and therefore it should not be used as the first study for male patients. Therefore, arguments for and against using voiding urosonography are similar to that of VCUG with the exception of male patients.

#### **Nuclear Medicine Cystography**

Some studies have suggested equal sensitivity for Tc-99m pertechnetate radionuclide cystography and VCUG [46], whereas others have indicated that radionuclide cystography has improved sensitivity for VUR in infants up to 1 year of age [47]. The main disadvantage of radionuclide cystography is that it does not provide anatomical details of the bladder and urethra and therefore should not be used as the first study for male patients. Therefore, arguments for and against using radionuclide cystography are similar to that of VCUG with the exception of male patients.

#### **DTPA Renal Scan**

There is no relevant literature to support the routine use of Tc-99m DTPA renal scan in the setting of a normal neonatal US.

### **MAG3 Renal Scan**

There is no relevant literature to support the routine use of Tc-99m MAG3 diuretic renal scan in the setting of a normal neonatal US.

### **MRI Abdomen and Pelvis**

There is no relevant literature to support the routine use of MRU in the in the setting of a normal neonatal US.

### **Variant 3: Antenatal diagnosis of hydronephrosis with isolated mild (SFU grade 1 and 2 or APRPD less than 15 mm) hydronephrosis on initial neonatal ultrasound.**

#### **US Kidneys and Bladder Retroperitoneal Follow-Up in 1–6 Months**

Studies have confirmed the possibility of development of significant urinary tract conditions with even mild hydronephrosis on prenatal and initial postnatal imaging [8]. Therefore, mild findings on postnatal renal US do not exclude a urinary tract abnormality. Given the late development of some urinary tract abnormalities, a repeat US is recommended by some authors, suggesting this examination be performed at 1 to 6 months [4,5,49,50]. However, in children with mild hydronephrosis, there has shown to be a low risk of underlying anatomic abnormality, including UPJO [10].

#### **Fluoroscopic Voiding Cystourethrography**

There is controversy regarding whether all children with antenatal hydronephrosis should undergo VCUG. A meta-analysis by the American Urology Association found that, on average, approximately 16% of neonates and infants with antenatal hydronephrosis will have VUR. The incidence of VUR was independent of degree of antenatal hydronephrosis, and a quarter of these were found to have no hydronephrosis on postnatal US [31]. There is disagreement over whether this VUR is clinically significant and therefore over the need for diagnosis. Some authors advocate VCUG for all infants with antenatal hydronephrosis, to guide treatment with prophylactic antibiotics [20,27,32,33]. However, currently, most authors (including the 2010 SFU consensus statement) recommend against routine VCUG for antenatal hydronephrosis [2,12,29,34,35]. This is largely because the benefit of prophylactic antibiotic in children with UTI has not been clearly demonstrated [36]. The efficacy of prophylactic antibiotics in preventing UTIs or renal damage in patients with antenatal hydronephrosis, with or without VUR, is difficult to determine because of variability in methods and results [39]. In addition, most of the VUR spontaneously resolves [40]. One of the potential risks of VCUG is iatrogenic UTI. This was reported in about 2% of VCUG studies performed for evaluation of antenatal hydronephrosis [39].

#### **Voiding Urosonography**

Multiple recent investigations evaluating real-time contrast-enhanced US techniques have demonstrated a high degree of diagnostic accuracy, and some demonstrated increased sensitivity as compared to fluoroscopic VCUG in the detection of VUR [41-45]. The main potential disadvantage of voiding urosonography is a lower anatomical detail of the bladder and urethra, and therefore it should not be used as the first study for male patients. Therefore, arguments for and against using voiding urosonography are similar to that of VCUG with the exception of male patients.

#### **Nuclear Medicine Cystography**

Some studies have suggested equal sensitivity for Tc-99m pertechnetate radionuclide cystography and VCUG [46], whereas others have indicated that radionuclide cystography has improved sensitivity for VUR in infants up to 1 year of age [47]. The main disadvantage of radionuclide cystography is that it does not provide anatomical details of the bladder and urethra and therefore should not be used as the first study for male patients. Therefore, arguments for and against using radionuclide cystography are similar to that of VCUG with the exception of male patients.

#### **DTPA Renal Scan**

There is no relevant literature to support the routine use of Tc-99m DTPA renal scan as the first imaging in the evaluation of mild antenatal hydronephrosis, because there is low risk of underlying anatomic abnormality such as UPJO in the setting of mild hydronephrosis.

#### **MAG3 Renal Scan**

There is no relevant literature to support the routine use of Tc-99m MAG3 diuretic renal scan as the first imaging in the evaluation of mild antenatal hydronephrosis, because there is low risk of underlying anatomic abnormality such as UPJO in the setting of mild hydronephrosis.

#### **MRI abdomen and pelvis**

There is no relevant literature to support the routine use of MRU in the initial evaluation of mild antenatal hydronephrosis.

**Variant 4: Male. Antenatal diagnosis of hydronephrosis with moderate or severe (SFU grade 3 or 4 or APRPD greater than 15 mm) hydronephrosis on initial neonatal ultrasound, or hydronephrosis associated with parenchymal abnormalities, hydroureter, bladder wall thickening, or posterior urethral dilation.**

#### **US Kidneys and Bladder Retroperitoneal Follow-Up in 1–6 Months**

The two most common diagnostic considerations in this situation are VUR and UPJO. Less commonly, PUV or primary megaureter can occur with PUV being the most common cause of neonatal bladder outlet obstruction. PUV occurs in 0.2% to 1% of cases of mild antenatal hydronephrosis but is more frequent (up to 6%) in the setting of more severe antenatal hydronephrosis [51]. With a high index of suspicion for PUV, such as bladder wall-thickening and dilated posterior urethra on US imaging, the bladder should be catheterized at birth to decompress the urinary tract. Beginning prophylactic antibiotics should also be considered [34,50,52]. With more severe postnatal hydronephrosis detected, the need for further workup heightens. Even in the setting of abnormal findings on initial neonatal US, further follow-up US between 1 and 6 months may be useful to re-evaluate a dilated urinary tract after bladder catheterization [1,21,23,53-55].

#### **Fluoroscopic Voiding Cystourethrography**

The purpose of VCUG is to identify the presence of VUR. VUR accounts for 30% of urinary tract abnormalities in infants with antenatal hydronephrosis [31]. In a meta-analysis by Lee et al [51] of over 1,300 subjects, the overall incidence of urinary tract pathology increased with increasing antenatal hydronephrosis, but the risk of VUR was similar for all subjects. Some authors have shown that with higher grades of postnatal hydronephrosis, the severity of VUR increases [56]. In one study, 121 children were evaluated, and all who had severe VUR had a renal pelvis diameter of  $\geq 10$  mm [56]. In a recent multidisciplinary consensus statement on urinary tract dilation, recommendations are for a 1-month US examination and VCUG, in the moderate or severe neonatal hydronephrosis [3].

VUR can be either primary or secondary to other urologic abnormalities. In male patients with moderate or severe hydronephrosis found on neonatal US, VCUG has a role in the evaluation of urologic abnormalities that may need immediate care, and bladder outlet obstruction from PUV must be excluded [12,20,28,29,50,57]. The catheter placed for initial bladder decompression can be used for this study. There is no need to remove the bladder catheter to assess for PUV [58]. Frequently, the study will show VUR in addition to bladder wall thickening and the dilated posterior urethra. When the diagnosis of PUV is made, immediate referral to urology is needed. Furthermore, it can reveal other anomalies such as a duplex collecting system, which helps to determine whether the reflux is primary or secondary.

Other infants with severe or bilateral moderate antenatal hydronephrosis may have VUR in isolation. There is higher risk for UTI in children with VUR [59]. Although the benefit of prophylactic antibiotics in this population is unknown, some authors recommend beginning antibiotics on these patients [26,60].

#### **Voiding Urosonography**

Multiple recent investigations evaluating real-time contrast-enhanced US techniques have demonstrated a high degree of diagnostic accuracy, and some demonstrated increased sensitivity compared to fluoroscopic VCUG in the detection of VUR [41-45]. However, given the significant disadvantage of voiding urosonography in providing lower anatomical detail of the bladder and urethra, it should not be used as the first study for male patients.

#### **Nuclear Medicine Cystography**

Although some studies have suggested equal sensitivity for Tc-99m pertechnetate radionuclide cystography and VCUG [46], it does not provide sufficient anatomical detail of the bladder and urethra and therefore should not be used as the first study for male patients.

#### **DTPA Renal Scan**

Tc-99m DTPA is excreted primarily by glomerular filtration. Its extraction fraction is approximately 20% accounting for greater background, versus renal, activity compared to MAG3 [61]. Tc-99m DTPA renal scan provides information on renal function and urinary tract drainage based on split renal function and renal washout curves and can be useful for the evaluation of severe grade 3 and 4 hydronephrosis in concert with VCUG [20,29,53,62,63]. Given the lower glomerular filtration rate in newborns, these examinations are frequently delayed until at least 2 months of age [29,63-65]. However, because of its rapid renal clearance and primary excretion by the tubules on which furosemide acts, Tc-99m MAG3 is preferred over Tc-99m DTPA in patients with suspected obstruction or impaired renal function [61].



### **MAG3 Renal Scan**

Tc-99m MAG3 is primarily excreted through active renal tubular transport, and its extraction fraction is 40% to 50% [61]. This greater extraction fraction, versus DTPA, accounts for less background, versus renal, activity compared to DTPA. Because of its rapid renal clearance and primary excretion by the tubules on which furosemide acts, Tc-99m MAG3 is preferred over Tc-99m DTPA in patients with suspected obstruction or impaired renal function [61]. Tc-99m MAG3 renal scan is useful for the evaluation of severe grade 3 and 4 hydronephrosis and may be performed in concert with a VCUg study [20,29,53,62,63]. Tc-99m MAG3 renal scan provides information on renal function and urinary tract drainage based on split renal function [61].

Diuretic renal scan is used for diagnosis of multiple causes of obstruction, including primary obstructing megaureter [52,66-68]. Approximately 5% to 10% of antenatal hydronephrosis is attributable to primary megaureter [4,69] diagnosed by persistent ureteral dilation (>7 mm). Primary megaureter is classified according to the presence or absence of reflux and obstruction. Most will resolve spontaneously [20,70-72]. Surgical intervention is decided based on evidence of obstruction and depends upon  $T_{1/2}$  of time activity curve ( $T_{1/2}$ >20 minutes), decreased renal function (<40% differential renal function), deteriorating function (>5% change on consecutive renal scans), or worsening drainage on serial imaging. Tc-99m MAG3 renal scan can be used to monitor function over time, with a decrease in differential renal function on the affected side often serving as an indicator of a need for intervention [55,73].

### **MRI Abdomen and Pelvis**

There is no consensus on the role of MRU, performed without and with intravenous (IV) contrast, in patients with moderate to severe postnatal hydronephrosis especially before VCUg is performed. Although MRU is not routinely recommended in the initial workup of antenatal hydronephrosis, some authors have argued that it can add value through improved anatomical imaging, for example, in the evaluation of hydronephrosis in the setting of atypical urinary tract anatomy, such as certain duplicated collecting systems or renal dysgenesis [74]. MRU can also adequately assess degree of obstruction [75]. One potential limitation of MRU is that there are systematic differences in estimation of split renal function compared with the gold standard MAG-3 renal scan in kidneys with severely diminished renal function [75] and kidneys with severe hydronephrosis [76].

**Variant 5: Female. Antenatal diagnosis of hydronephrosis with moderate or severe (SFU grade 3 or 4 or APRPD greater than 15 mm) hydronephrosis on initial neonatal ultrasound, or hydronephrosis associated with parenchymal abnormalities, hydroureter, bladder wall thickening.**

### **US Kidneys and Bladder Retroperitoneal Follow-Up in 1–6 Months**

The two most common diagnostic considerations in this situation are VUR and UPJO. Less commonly, primary megaureter can occur. Beginning prophylactic antibiotics may be considered [34,50,52]. With more severe postnatal hydronephrosis detected, the need for further workup heightens. Even in the setting of abnormal findings on initial neonatal US, further follow-up US between 1 and 6 months may be useful to re-evaluate a dilated urinary tract after bladder catheterization [1,21,23,53-55].

### **Fluoroscopic Voiding Cystourethrography**

The purpose of VCUg is to identify the presence of VUR. VUR accounts for 30% of urinary tract abnormalities in infants with antenatal hydronephrosis [31]. In a meta-analysis by Lee et al [51] of over 1,300 subjects, the overall incidence of urinary tract pathology increased with increasing antenatal hydronephrosis, but the risk of VUR was similar for all subjects. Some authors have shown that with higher grades of postnatal hydronephrosis, the severity of VUR increases [56]. In one study, 121 children were evaluated, and all who had severe VUR had a renal pelvis diameter of  $\geq 10$  mm [56]. In a recent multidisciplinary consensus statement on urinary tract dilation, recommendations are for a 1-month US examination and VCUg, in the moderate or severe neonatal hydronephrosis [3].

VUR can be either primary or secondary to other urologic abnormalities. In patients with moderate or severe hydronephrosis found on neonatal US, VCUg has a role in the evaluation of urologic abnormalities that may need immediate care [12,20,28,29,50,57]. Furthermore, it can reveal other anomalies, such as a duplex collecting system, which help to determine whether the reflux is primary or secondary.

Other infants with severe or bilateral moderate antenatal hydronephrosis may have VUR in isolation. There is higher risk for UTI in children with VUR [59]. Although the benefit of prophylactic antibiotics in this population is unknown, some authors recommend beginning antibiotics on these patients [26,60].

### **Voiding Urosonography**

Multiple recent investigations evaluating real-time contrast-enhanced US techniques have demonstrated a high degree of diagnostic accuracy, and some demonstrated increased sensitivity as compared to fluoroscopic VCUG in the detection of VUR [41-45]. The main potential disadvantage of voiding urosonography is a lower anatomical detail of the bladder, but otherwise, arguments for and against using voiding urosonography are similar to that of VCUG.

### **Nuclear Medicine Cystography**

Some studies have suggested equal sensitivity for Tc-99m pertechnetate radionuclide cystography and VCUG [46], whereas others have indicated that radionuclide cystography has improved sensitivity for VUR in infants up to 1 year of age [47]. Arguments for and against using radionuclide cystography are similar to that of VCUG for the female patient.

### **DTPA Renal Scan**

Tc-99m DTPA is excreted primarily by glomerular filtration. Its extraction fraction is approximately 20% accounting for greater background, versus renal, activity compared to MAG3 [61]. Tc-99m DTPA renal scan provides information on renal function and urinary tract drainage based on split renal function and renal washout curves and can be useful for the evaluation of severe grade 3 and 4 hydronephrosis in concert with VCUG [20,29,53,62,63]. Given the lower glomerular filtration rate in newborns, these examinations are frequently delayed until at least 2 months of age [29,63-65]. However, because of its rapid renal clearance and primary excretion by the tubules on which furosemide acts, Tc-99m MAG3 is preferred over Tc-99m DTPA in patients with suspected obstruction or impaired renal function [61].

### **MAG3 Renal Scan**

Tc-99m MAG3 is primarily excreted through active renal tubular transport, and its extraction fraction is 40% to 50% [61]. This greater extraction fraction, versus DTPA, accounts for less background, versus renal, activity compared to DTPA. Because of its rapid renal clearance and primary excretion by the tubules on which furosemide acts, Tc-99m MAG3 is preferred over Tc-99m DTPA in patients with suspected obstruction or impaired renal function [61]. Tc-99m MAG3 renal scan is useful for the evaluation of severe grade 3 and 4 hydronephrosis and may be performed in concert with a VCUG study [20,29,53,62,63]. Tc-99m MAG3 renal scan provides information on renal function and urinary tract drainage based on split renal function [61].

Diuretic renal scan is used for diagnosis of multiple causes of obstruction, including primary obstructing megaureter [52,66-68]. Approximately 5% to 10% of antenatal hydronephrosis is attributable to primary megaureter [4,69] diagnosed by persistent ureteral dilation (>7 mm). Primary megaureter is classified according to the presence or absence of reflux and obstruction. Most will resolve spontaneously [20,70-72].

Surgical intervention is decided based on evidence of obstruction and depends upon  $T_{1/2}$  of time activity curve ( $T_{1/2}$  >20 minutes), decreased renal function (<40% differential renal function), deteriorating function (>5% change on consecutive renal scans), or worsening drainage on serial imaging. Tc-99m MAG3 renal scan can be used to monitor function over time, with a decrease in differential renal function on the affected side often serving as an indicator of a need for intervention [55,73].

### **MRI Abdomen and Pelvis**

There is no consensus on the role of MRU, performed without and with IV contrast, in patients with moderate to severe postnatal hydronephrosis especially before VCUG is performed. Although MRU is not routinely recommended in the initial workup of antenatal hydronephrosis, some authors have argued that it can add value through improved anatomical imaging, for example, in the evaluation of hydronephrosis in the setting of atypical urinary tract anatomy, such as certain duplicated collecting systems or renal dysgenesis [74]. MRU can also adequately assess degree of obstruction [75]. One potential limitation of MRU is inaccurate estimation of split renal function compared with renal scan in kidneys with severely diminished renal function [75] and kidneys with severe hydronephrosis [76].

### **Variant 6: Antenatal diagnosis of hydronephrosis with moderate or severe (SFU grade 3 or 4 or APRPD greater than 15 mm) hydronephrosis on initial neonatal ultrasound and no evidence of reflux on VCUG.**

#### **US Kidneys and Bladder Retroperitoneal Follow-Up in 1–6 Months**

When moderate or severe antenatal hydronephrosis is present on initial neonatal US, and VUR is not present, obstructive causes of hydronephrosis must be excluded. In the absence of hydroureter or high grade VUR, UPJO

should be considered [6,29,53,77]. Of the causes of hydronephrosis, UPJO accounts for approximately 10% to 65% of cases and in 90% of cases the obstruction is unilateral [2,4,22,48]. As the severity of hydronephrosis increases, the risk of UPJO also increases, and as much as 35% of significant hydronephrosis (>10 mm APRPD postnatally) was attributable to UPJO in one study. Lee et al [51] showed a 54% risk of UPJO in severe (>15 mm APRPD postnatally) urinary tract dilation. Even in the setting of abnormal findings on initial neonatal US, further follow-up US between 1 and 6 months may be useful to re-evaluate a dilated urinary tract after bladder catheterization [1,21,23,53-55].

### **DTPA Renal Scan**

Tc-99m DTPA is excreted primarily by glomerular filtration. Its extraction fraction is approximately 20% accounting for greater background, versus renal, activity compared to MAG3 [61]. Tc-99m DTPA renal scan provides information on renal function and urinary tract drainage based on split renal function and renal washout curves and can be useful for the evaluation of severe grade 3 and 4 hydronephrosis [20,29,53,62,63]. Given the lower glomerular filtration rate in newborns, these examinations are frequently delayed until at least 2 months of age [29,63-65]. However, because of its rapid renal clearance and primary excretion by the tubules on which furosemide acts, Tc-99m MAG3 is preferred over Tc-99m DTPA in patients with suspected obstruction or impaired renal function [61].

### **MAG3 Renal Scan**

Tc-99m MAG3 is primarily excreted through active renal tubular transport, and its extraction fraction is 40% to 50%. This greater extraction fraction, versus DTPA, accounts for less background, versus renal, activity compared to DTPA. Because of its rapid renal clearance and primary excretion by the tubules on which furosemide acts, Tc-99m MAG3 is preferred over Tc-99m DTPA in patient with suspected obstruction or impaired renal function [61]. Tc-99m MAG3 renal scan provides information on split renal function and urinary tract drainage based on renal washout curve [3,22,27,28].

Diuretic renal scan is used for diagnosis of multiple causes of obstruction, including primary obstructing megaureter [52,66-68]. Approximately 5% to 10% of antenatal hydronephrosis is attributable to primary megaureter [4,69] diagnosed by persistent ureteral dilation (>7 mm). Primary megaureter is classified according to the presence or absence of reflux and obstruction. Most will resolve spontaneously [20,70-72].

Surgical intervention is decided based on evidence of obstruction based on  $T_{1/2}$  of time activity curve ( $T_{1/2}$  >20 minutes), decreased renal function (<40% differential renal function), deteriorating function (>5% change on consecutive renal scans), or worsening drainage on serial imaging [55,73]. Tc-99m MAG3 renal scan can be used to monitor function over time, with a decrease in differential renal function on the affected side often serving as an indicator of a need for intervention [55,73].

### **MRI Abdomen and Pelvis**

There is no consensus on the role of MRU, performed without and with IV contrast, in patients with moderate to severe postnatal hydronephrosis. Although MRU is not routinely recommended in the initial workup of antenatal hydronephrosis, some authors have argued that it can add value through improved anatomical imaging, for example, in the evaluation of hydronephrosis in the setting of atypical urinary tract anatomy, such as certain duplicated collecting systems or renal dysgenesis [74]. MRU can also adequately assess degree of obstruction [75]. One potential limitation of MRU is that there are systematic differences in estimation of split renal function compared with renal scan in kidneys with severely diminished renal function and kidneys with severe hydronephrosis [76].

### **Summary of Recommendations**

- **Variante 1:** US kidneys and bladder retroperitoneal is usually appropriate for the initial imaging of neonates with an antenatal diagnosis of hydronephrosis.
- **Variante 2:** A follow-up in 1 to 6 months with an US kidneys and bladder retroperitoneal is usually appropriate for neonates with a normal US and an antenatal diagnosis of hydronephrosis.
- **Variante 3:** A follow-up in 1 to 6 months with an US kidneys and bladder retroperitoneal is usually appropriate for neonates with an antenatal diagnosis of hydronephrosis and isolated mild (SFU grade 1 and 2) hydronephrosis on initial US.
- **Variante 4:** US kidneys and bladder retroperitoneal follow-up in 1 to 6 months, fluoroscopy VCUG, or MAG3 renal scan is usually appropriate for a male child with an antenatal diagnosis of hydronephrosis and moderate

or severe (SFU grade 3 or 4 or APRPD >15 mm) hydronephrosis on initial neonatal US, or hydronephrosis associated with parenchymal abnormalities, hydroureter, bladder wall thickening, or posterior urethral dilation. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient’s care).

- **Variation 5:** US kidneys and bladder retroperitoneal follow-up in 1 to 6 months, fluoroscopy VCUG, voiding urosonography, or MAG3 renal scan is usually appropriate for a female child with an antenatal diagnosis of hydronephrosis and moderate or severe (SFU grade 3 or 4 or APRPD >15 mm) hydronephrosis on initial neonatal US, or hydronephrosis associated with parenchymal abnormalities, hydroureter, or bladder wall thickening. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient’s care).
- **Variation 6:** US kidneys and bladder retroperitoneal follow-up in 1 to 6 months or MAG3 renal scan is usually appropriate for a child with no evidence of reflux on VCUG on initial US and an antenatal diagnosis of hydronephrosis with moderate or severe (SFU grade 3 or 4 or APRPD greater than 15 mm) hydronephrosis. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient’s care).

### Supporting Documents

The evidence table, literature search, and appendix for this topic are available at <https://acsearch.acr.org/list>. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to [www.acr.org/ac](http://www.acr.org/ac).

### Appropriateness Category Names and Definitions

| Appropriateness Category Name     | Appropriateness Rating | Appropriateness Category Definition  |
|-----------------------------------|------------------------|--|
| Usually Appropriate               | 7, 8, or 9             | The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.  |
| May Be Appropriate                | 4, 5, or 6             | The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal. |
| May Be Appropriate (Disagreement) | 5                      | The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel’s recommendation. “May be appropriate” is the rating category and a rating of 5 is assigned.                   |
| Usually Not Appropriate           | 1, 2, or 3             | The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.  |

### Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for

pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document [78].

| Relative Radiation Level Designations |                                     |   |
|---------------------------------------|-------------------------------------|---|
| Relative Radiation Level*             | Adult Effective Dose Estimate Range | Pediatric Effective Dose Estimate Range |
| ○                                     | 0 mSv                               | 0 mSv                                   |
| ☸                                     | <0.1 mSv                            | <0.03 mSv                               |
| ☸☸                                    | 0.1-1 mSv                           | 0.03-0.3 mSv                            |
| ☸☸☸                                   | 1-10 mSv                            | 0.3-3 mSv                               |
| ☸☸☸☸                                  | 10-30 mSv                           | 3-10 mSv                                |
| ☸☸☸☸☸                                 | 30-100 mSv                          | 10-30 mSv                               |

\*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as “Varies.”

## References

1. Longpre M, Nguan A, Macneily AE, Afshar K. Prediction of the outcome of antenatally diagnosed hydronephrosis: a multivariable analysis. *J Pediatr Urol* 2012;8:135-9.
2. Mallik M, Watson AR. Antenatally detected urinary tract abnormalities: more detection but less action. *Pediatr Nephrol* 2008;23:897-904.
3. Nguyen HT, Benson CB, Bromley B, et al. Multidisciplinary consensus on the classification of prenatal and postnatal urinary tract dilation (UTD classification system). *J Pediatr Urol* 2014;10:982-98.
4. Nguyen HT, Herndon CD, Cooper C, et al. The Society for Fetal Urology consensus statement on the evaluation and management of antenatal hydronephrosis. *J Pediatr Urol* 2010;6:212-31.
5. Matsui F, Shimada K, Matsumoto F, Takano S. Late recurrence of symptomatic hydronephrosis in patients with prenatally detected hydronephrosis and spontaneous improvement. *J Urol* 2008;180:322-5; discussion 25.
6. Passerotti CC, Kalish LA, Chow J, et al. The predictive value of the first postnatal ultrasound in children with antenatal hydronephrosis. *J Pediatr Urol* 2011;7:128-36.
7. Pates JA, Dashe JS. Prenatal diagnosis and management of hydronephrosis. *Early Hum Dev* 2006;82:3-8.
8. Signorelli M, Cerri V, Taddei F, Groli C, Bianchi UA. Prenatal diagnosis and management of mild fetal pyelectasis: implications for neonatal outcome and follow-up. *Eur J Obstet Gynecol Reprod Biol* 2005;118:154-9.
9. Fernbach SK, Maizels M, Conway JJ. Ultrasound grading of hydronephrosis: introduction to the system used by the Society for Fetal Urology. *Pediatr Radiol* 1993;23:478-80.
10. Sidhu G, Beyene J, Rosenblum ND. Outcome of isolated antenatal hydronephrosis: a systematic review and meta-analysis. *Pediatr Nephrol* 2006;21:218-24.
11. Duin LK, Willekes C, Koster-Kamphuis L, Offermans J, Nijhuis JG. Fetal hydronephrosis: does adding an extra parameter improve detection of neonatal uropathies? *J Matern Fetal Neonatal Med* 2012;25:920-3.
12. Riccabona M, Avni FE, Blickman JG, et al. Imaging recommendations in paediatric urology: minutes of the ESPR workgroup session on urinary tract infection, fetal hydronephrosis, urinary tract ultrasonography and voiding cystourethrography, Barcelona, Spain, June 2007. *Pediatr Radiol* 2008;38:138-45.
13. Chow JS, Darge K. Multidisciplinary consensus on the classification of antenatal and postnatal urinary tract dilation (UTD classification system). *Pediatr Radiol* 2015;45:787-9.
14. Swenson DW, Darge K, Ziniel SI, Chow JS. Characterizing upper urinary tract dilation on ultrasound: a survey of North American pediatric radiologists' practices. *Pediatr Radiol* 2015;45:686-94.
15. Keays MA, Guerra LA, Mihill J, et al. Reliability assessment of Society for Fetal Urology ultrasound grading system for hydronephrosis. *J Urol* 2008;180:1680-2; discussion 82-3.
16. Kim SY, Kim MJ, Yoon CS, Lee MS, Han KH, Lee MJ. Comparison of the reliability of two hydronephrosis grading systems: the Society for Foetal Urology grading system vs. the Onen grading system. *Clin Radiol* 2013;68:e484-90.

17. de Kort EH, Bambang Oetomo S, Zegers SH. The long-term outcome of antenatal hydronephrosis up to 15 millimetres justifies a noninvasive postnatal follow-up. *Acta Paediatr* 2008;97:708-13.
18. Dias CS, Silva JM, Pereira AK, et al. Diagnostic accuracy of renal pelvic dilatation for detecting surgically managed ureteropelvic junction obstruction. *J Urol* 2013;190:661-6.
19. Abdulaziz Kari J, Habiballah S, Alsaedi SA, et al. Incidence and outcomes of antenatally detected congenital hydronephrosis. *Ann Saudi Med* 2013;33:260-4.
20. Belarmino JM, Kogan BA. Management of neonatal hydronephrosis. *Early Hum Dev* 2006;82:9-14.
21. Coelho GM, Bouzada MC, Pereira AK, et al. Outcome of isolated antenatal hydronephrosis: a prospective cohort study. *Pediatr Nephrol* 2007;22:1727-34.
22. Fefer S, Ellsworth P. Prenatal hydronephrosis. *Pediatr Clin North Am* 2006;53:429-47, vii.
23. Gokaslan F, Yalcinkaya F, Fitoz S, Ozcakar ZB. Evaluation and outcome of antenatal hydronephrosis: a prospective study. *Ren Fail* 2012;34:718-21.
24. Sharifian M, Esfandiar N, Mohkam M, Dalirani R, Baban Taher E, Akhlaghi A. Diagnostic accuracy of renal pelvic dilatation in determining outcome of congenital hydronephrosis. *Iran J Kidney Dis* 2014;8:26-30.
25. Sinha A, Bagga A, Krishna A, et al. Revised guidelines on management of antenatal hydronephrosis. *Indian Pediatr* 2013;50:215-31.
26. Aksu N, Yavascan O, Kangin M, et al. Postnatal management of infants with antenatally detected hydronephrosis. *Pediatr Nephrol* 2005;20:1253-9.
27. Kitchens DM, Herndon CD. Postnatal imaging of antenatal hydronephrosis. *ScientificWorldJournal* 2009;9:393-9.
28. Riccabona M. Assessment and management of newborn hydronephrosis. *World J Urol* 2004;22:73-8.
29. Yamacake KG, Nguyen HT. Current management of antenatal hydronephrosis. *Pediatr Nephrol* 2013;28:237-43.
30. Becker AM. Postnatal evaluation of infants with an abnormal antenatal renal sonogram. *Curr Opin Pediatr* 2009;21:207-13.
31. Skoog SJ, Peters CA, Arant BS, Jr., et al. Pediatric Vesicoureteral Reflux Guidelines Panel Summary Report: Clinical Practice Guidelines for Screening Siblings of Children With Vesicoureteral Reflux and Neonates/Infants With Prenatal Hydronephrosis. *J Urol* 2010;184:1145-51.
32. Estrada CR, Jr. Prenatal hydronephrosis: early evaluation. *Curr Opin Urol* 2008;18:401-3.
33. Tibballs JM, De Bruyn R. Primary vesicoureteric reflux--how useful is postnatal ultrasound? *Arch Dis Child* 1996;75:444-7.
34. Assadi F, Schloemer N. Simplified diagnostic algorithm for evaluation of neonates with prenatally detected hydronephrosis. *Iran J Kidney Dis* 2012;6:284-90.
35. Berrocal T, Pinilla I, Gutierrez J, Prieto C, de Pablo L, Del Hoyo ML. Mild hydronephrosis in newborns and infants: can ultrasound predict the presence of vesicoureteral reflux. *Pediatr Nephrol* 2007;22:91-6.
36. Koyle MA, Shifrin D. Issues in febrile urinary tract infection management. *Pediatr Clin North Am* 2012;59:909-22.
37. Robinson JL, Finlay JC, Lang ME, Bortolussi R, Canadian Paediatric Society CPCID, Immunization C. Prophylactic antibiotics for children with recurrent urinary tract infections. *Paediatr Child Health* 2015;20:45-51.
38. Lee T, Park JM. Vesicoureteral reflux and continuous prophylactic antibiotics. *Investig Clin Urol* 2017;58:S32-S37.
39. Visuri S, Jahnukainen T, Taskinen S. Incidence of urinary tract infections in infants with antenatally diagnosed hydronephrosis-A retrospective single center study. *J Pediatr Surg* 2017;52:1503-06.
40. Herndon CD, McKenna PH, Kolon TF, Gonzales ET, Baker LA, Docimo SG. A multicenter outcomes analysis of patients with neonatal reflux presenting with prenatal hydronephrosis. *J Urol* 1999;162:1203-8.
41. Darge K, Heidemeier A. [Modern ultrasound technologies and their application in pediatric urinary tract imaging]. *Radiologie* 2005;45:1101-11.
42. Giordano M, Marzolla R, Puteo F, Scianaro L, Caringella DA, Depalo T. Voiding urosonography as first step in the diagnosis of vesicoureteral reflux in children: a clinical experience. *Pediatr Radiol* 2007;37:674-7.
43. Kis E, Nyitrai A, Varkonyi I, et al. Voiding urosonography with second-generation contrast agent versus voiding cystourethrography. *Pediatr Nephrol* 2010;25:2289-93.
44. Wong LS, Tse KS, Fan TW, et al. Voiding urosonography with second-generation ultrasound contrast versus micturating cystourethrography in the diagnosis of vesicoureteric reflux. *Eur J Pediatr* 2014;173:1095-101.

45. Wozniak MM, Wieczorek AP, Pawelec A, et al. Two-dimensional (2D), three-dimensional static (3D) and real-time (4D) contrast enhanced voiding urosonography (ceVUS) versus voiding cystourethrography (VCUG) in children with vesicoureteral reflux. *Eur J Radiol* 2016;85:1238-45.
46. Fretzayas A, Karpathios T, Dimitriou P, Nicolaidou P, Matsaniotis N. Grading of vesicoureteral reflux by radionuclide cystography. *Pediatr Radiol* 1984;14:148-50.
47. McLaren CJ, Simpson ET. Direct comparison of radiology and nuclear medicine cystograms in young infants with vesico-ureteric reflux. *BJU Int* 2001;87:93-7.
48. Gokce I, Biyikli N, Tugtepe H, Tarcan T, Alpay H. Clinical spectrum of antenatally detected urinary tract abnormalities with respect to hydronephrosis at postnatal ultrasound scan. *Pediatr Surg Int* 2012;28:543-52.
49. Alconcher LF, Tombesi MM. Natural history of bilateral mild isolated antenatal hydronephrosis conservatively managed. *Pediatr Nephrol* 2012;27:1119-23.
50. Vemulakonda V, Yiee J, Wilcox DT. Prenatal hydronephrosis: postnatal evaluation and management. *Curr Urol Rep* 2014;15:430.
51. Lee RS, Cendron M, Kinnamon DD, Nguyen HT. Antenatal hydronephrosis as a predictor of postnatal outcome: a meta-analysis. *Pediatrics* 2006;118:586-93.
52. Herndon CD. Antenatal hydronephrosis: differential diagnosis, evaluation, and treatment options. *ScientificWorldJournal* 2006;6:2345-65.
53. Herndon CD, Kitchens DM. The management of ureteropelvic junction obstruction presenting with prenatal hydronephrosis. *ScientificWorldJournal* 2009;9:400-3.
54. McMann LP, Kirsch AJ, Scherz HC, et al. Magnetic resonance urography in the evaluation of prenatally diagnosed hydronephrosis and renal dysgenesis. *J Urol* 2006;176:1786-92.
55. Yang Y, Hou Y, Niu ZB, Wang CL. Long-term follow-up and management of prenatally detected, isolated hydronephrosis. *J Pediatr Surg* 2010;45:1701-6.
56. Grazioli S, Parvex P, Merlini L, Combescure C, Girardin E. Antenatal and postnatal ultrasound in the evaluation of the risk of vesicoureteral reflux. *Pediatr Nephrol* 2010;25:1687-92.
57. Kitchens DM, Herndon CD. Antenatal hydronephrosis. *Curr Urol Rep* 2009;10:126-33.
58. Ditchfield MR, Grattan-Smith JD, de Campo JF, Hutson JM. Voiding cystourethrography in boys: does the presence of the catheter obscure the diagnosis of posterior urethral valves? *AJR Am J Roentgenol* 1995;164:1233-5.
59. Jacobson SH, Hansson S, Jakobsson B. Vesico-ureteric reflux: occurrence and long-term risks. *Acta Paediatr Suppl* 1999;88:22-30.
60. Braga LH, Farrokhyar F, D'Cruz J, Pemberton J, Lorenzo AJ. Risk factors for febrile urinary tract infection in children with prenatal hydronephrosis: a prospective study. *J Urol* 2015;193:1766-71.
61. Taylor AT. Radionuclides in nephrourology, part 1: Radiopharmaceuticals, quality control, and quantitative indices. *J Nucl Med* 2014;55:608-15.
62. Jain V, Agarwala S, Bhatnagar V, Gupta AK, Kumar R, Bal CS. Long term outcome of management of antenatally diagnosed pelvi-ureteric junction obstruction. *Indian J Pediatr* 2012;79:769-73.
63. Ylinen E, Ala-Houhala M, Wikstrom S. Outcome of patients with antenatally detected pelviureteric junction obstruction. *Pediatr Nephrol* 2004;19:880-7.
64. Eskild-Jensen A, Gordon I, Piepsz A, Frokiaer J. Congenital unilateral hydronephrosis: a review of the impact of diuretic renography on clinical treatment. *J Urol* 2005;173:1471-6.
65. Piepsz A, Sixt R, Gordon I. Performing renography in children with antenatally detected pelvi-ureteric junction stenosis: errors, pitfalls, controversies. *Q J Nucl Med Mol Imaging* 2010;54:350-62.
66. Chertin B, Pollack A, Koulikov D, et al. Long-term follow up of antenatally diagnosed megaureters. *J Pediatr Urol* 2008;4:188-91.
67. Shukla AR, Cooper J, Patel RP, et al. Prenatally detected primary megaureter: a role for extended followup. *J Urol* 2005;173:1353-6.
68. Zampieri N, Zamboni C, Camoglio FS. Clinical course of grade I-III megaureters detected on prenatal ultrasound. *Minerva Pediatr* 2011;63:439-43.
69. Arena S, Magno C, Montalto AS, et al. Long-term follow-up of neonatally diagnosed primary megaureter: rate and predictors of spontaneous resolution. *Scand J Urol Nephrol* 2012;46:201-7.
70. Di Renzo D, Aguiar L, Cascini V, et al. Long-term followup of primary nonrefluxing megaureter. *J Urol* 2013;190:1021-6.

71. DiRenzo D, Persico A, DiNicola M, Silvaroli S, Martino G, LelliChiesa P. Conservative management of primary non-refluxing megaureter during the first year of life: A longitudinal observational study. *J Pediatr Urol* 2015;11:226 e1-6.
72. Farrugia MK, Hitchcock R, Radford A, Burki T, Robb A, Murphy F. British Association of Paediatric Urologists consensus statement on the management of the primary obstructive megaureter. *J Pediatr Urol* 2014;10:26-33.
73. Kumar S, Walia S, Ikpeme O, et al. Postnatal outcome of prenatally diagnosed severe fetal renal pelvic dilatation. *Prenat Diagn* 2012;32:519-22.
74. Adeb M, Darge K, Dillman JR, Carr M, Epelman M. Magnetic resonance urography in evaluation of duplicated renal collecting systems. *Magn Reson Imaging Clin N Am* 2013;21:717-30.
75. Rodigas J, Kirsch H, John U, et al. Static and Functional MR Urography to Assess Congenital Anomalies of the Kidney and Urinary Tract in Infants and Children: Comparison With MAG3 Renal Scintigraphy and Sonography. *AJR Am J Roentgenol* 2018;211:193-203.
76. Claudon M, Durand E, Grenier N, et al. Chronic urinary obstruction: evaluation of dynamic contrast-enhanced MR urography for measurement of split renal function. *Radiology* 2014;273:801-12.
77. Duong HP, Piepsz A, Collier F, et al. Predicting the clinical outcome of antenatally detected unilateral pelviureteric junction stenosis. *Urology* 2013;82:691-6.
78. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: <https://www.acr.org/-/media/ACR/Files/Appropriateness-Criteria/RadiationDoseAssessmentIntro.pdf>. Accessed March 27, 2020.

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.