American College of Radiology
ACR Appropriateness Criteria®
Hematuria-Child

Variant: 1 Child. Isolated microscopic hematuria (nonpainful, nontraumatic) without proteinuria. Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
Arteriography kidneys	Usually Not Appropriate	☢☢☢☢
US kidneys and bladder	Usually Not Appropriate	O
Voiding urosonography	Usually Not Appropriate	O
Fluoroscopy voiding cystourethrography	Usually Not Appropriate	☢☢
Radiography abdomen and pelvis	Usually Not Appropriate	☢☢☢
Radiography intravenous urography	Usually Not Appropriate	☢☢☢
MRI abdomen and pelvis without and with IV contrast	Usually Not Appropriate	O
MRI abdomen and pelvis without IV contrast	Usually Not Appropriate	O
CT abdomen and pelvis with IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢☢

Variant: 2 Child. Isolated microscopic hematuria (nonpainful, nontraumatic) with proteinuria. Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
US kidneys and bladder	Usually Appropriate	O
Arteriography kidneys	Usually Not Appropriate	☢☢☢☢
Voiding urosonography	Usually Not Appropriate	O
Fluoroscopy voiding cystourethrography	Usually Not Appropriate	☢☢
Radiography abdomen and pelvis	Usually Not Appropriate	☢☢☢
Radiography intravenous urography	Usually Not Appropriate	☢☢☢
MRI abdomen and pelvis without and with IV contrast	Usually Not Appropriate	O
MRI abdomen and pelvis without IV contrast	Usually Not Appropriate	O
CT abdomen and pelvis with IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢☢

Variant: 3 Child. Isolated macroscopic hematuria (nonpainful, nontraumatic). Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
US kidneys and bladder	Usually Appropriate	O
Arteriography kidneys	Usually Not Appropriate	☢☢☢☢
Voiding urosonography	Usually Not Appropriate	O
Fluoroscopy voiding cystourethrography	Usually Not Appropriate	☢☢
Radiography abdomen and pelvis	Usually Not Appropriate	☢☢☢
Radiography intravenous urography	Usually Not Appropriate	☢☢☢
MRI abdomen and pelvis without and with IV contrast	Usually Not Appropriate	O

MRI abdomen and pelvis without IV contrast	Usually Not Appropriate	O
CT abdomen and pelvis with IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢☢

Variant: 4 Child. Painful hematuria (nontraumatic). Suspected urolithiasis. Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
US kidneys and bladder	Usually Appropriate	O
CT abdomen and pelvis without IV contrast	Usually Appropriate	☢☢☢☢
Radiography abdomen and pelvis	May Be Appropriate	☢☢☢
Arteriography kidneys	Usually Not Appropriate	☢☢☢☢
Voiding urosonography	Usually Not Appropriate	O
Fluoroscopy voiding cystourethrography	Usually Not Appropriate	☢☢
Radiography intravenous urography	Usually Not Appropriate	☢☢☢
MRI abdomen and pelvis without and with IV contrast	Usually Not Appropriate	O
MRI abdomen and pelvis without IV contrast	Usually Not Appropriate	O
CT abdomen and pelvis with IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢☢

Variant: 5 Child. Traumatic hematuria (macroscopic). Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
CT abdomen and pelvis with IV contrast	Usually Appropriate	☢☢☢☢
Fluoroscopy retrograde urethrography	May Be Appropriate	☢☢☢
CT pelvis with bladder contrast (CT cystography)	May Be Appropriate	☢☢☢☢
Arteriography kidneys	Usually Not Appropriate	☢☢☢☢
US kidneys and bladder	Usually Not Appropriate	O
Voiding urosonography	Usually Not Appropriate	O
Fluoroscopy voiding cystourethrography	Usually Not Appropriate	☢☢
Radiography abdomen and pelvis	Usually Not Appropriate	☢☢☢
Radiography intravenous urography	Usually Not Appropriate	☢☢☢
MRI abdomen and pelvis without and with IV contrast	Usually Not Appropriate	O
MRI abdomen and pelvis without IV contrast	Usually Not Appropriate	O
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢☢

Variant: 6 Child. Traumatic hematuria (microscopic). Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
CT abdomen and pelvis with IV contrast	Usually Appropriate	☢☢☢☢
US kidneys and bladder	May Be Appropriate	O
Fluoroscopy retrograde urethrography	May Be Appropriate	☢☢☢
CT pelvis with bladder contrast (CT cystography)	May Be Appropriate	☢☢☢☢
Arteriography kidneys	Usually Not Appropriate	☢☢☢☢
Voiding urosonography	Usually Not Appropriate	O
Fluoroscopy voiding cystourethrography	Usually Not Appropriate	☢☢

Radiography abdomen and pelvis	Usually Not Appropriate	☢☢☢
Radiography intravenous urography	Usually Not Appropriate	☢☢☢
MRI abdomen and pelvis without and with IV contrast	Usually Not Appropriate	O
MRI abdomen and pelvis without IV contrast	Usually Not Appropriate	O
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢☢

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Summary of Literature Review

Introduction/Background

Hematuria is the presence of red blood cells in the urine, either visible to the eye (macroscopic hematuria) or as viewed under the microscope (microscopic hematuria). Detecting blood in the urine of a child may cause alarm to patients, parents, and physicians.

The clinical evaluation of children with any form of hematuria begins with a meticulous history. Topics covered in the history commonly include urinary tract infection, strenuous exertion, tropical exposure, recent strep throat, recent trauma, menstruation, bleeding tendency, bloody diarrhea, joint pains, rash, flank pain, frequency, and dysuria. Searching for occult forms of trauma, foreign body insertion, family history of sickle cell disease or hemophilia, stone disease, hearing loss, familial renal disease [1,2], and hypertension should be undertaken. Factitious causes of "hematuria," such as food substances or medicines coloring the urine without actually having red blood cells in the urine, should also be investigated [3-5]. An assessment of the child's height and weight should be followed by a thorough physical examination. Fevers, arthritis, rashes, soft-tissue edema, nephromegaly, abdominal masses, genital or anal bleeding suggesting sexual abuse, deafness, and costovertebral angle tenderness should be discerned.

The next step is a thorough evaluation of the urine. Tea-colored urine and hematuria accompanied by proteinuria (>2+ by dip stick), red blood cell casts, and deformed red blood cells (best seen with phase contrast microscopy) suggest a glomerular source of hematuria (eg, glomerulonephritis) [6]. The presence of white cells and microorganisms within the urine clearly indicate the possibility of a urinary tract infection, which will direct care and imaging by a different set of criteria. Evaluation for hypercalciuria (such as a spot urine calcium/creatinine ratio) and a urine culture may be indicated. When concern for chronic kidney disease exists, basic laboratory metabolic screening in the initial evaluation should include blood urea nitrogen test, a serum creatinine test, and complete blood count with platelets. If suggested by the initial clinical workup, more advanced medical assessment for various causes of glomerulonephritis and vasculitis should be performed, and an audiogram and slit lamp examinations should be performed if there is suspicion for Alport syndrome [7-13].

The need for imaging evaluation depends on the clinical scenario in which hematuria presents. This review focuses on the following clinical variations of childhood hematuria:

- Isolated hematuria (nonpainful, nontraumatic)
- Painful hematuria
- Renal trauma with macroscopic hematuria
- Renal trauma with microscopic hematuria

In children with post-traumatic macroscopic hematuria, the role of imaging is to identify any evidence and the extent of renal or urinary tract injury. In other children, imaging has a role in identifying the cause of hematuria and to assess the size of the kidneys as an indicator of the chronicity of the renal disease and also as an assessment before renal biopsy. In this situation, ultrasound (US) is the best modality to display the anatomy, size, and position of the kidneys (especially prior to biopsy) and to screen for other pre-existing structural lesions. Definite medical diagnosis can sometimes be suggested by clinical evaluation (such as postinfectious glomerulonephritis, Henoch-Schönlein purpura, coagulopathy, sickle cell disease, systemic lupus erythematosus, or infection). In other cases, renal biopsy is necessary for the diagnosis of renal parenchymal diseases causing hematuria, such as IgA nephropathy (Berger disease) or Alport syndrome. However, many patients with isolated microscopic hematuria who are otherwise asymptomatic are followed clinically without more extensive workup [3,7,10,14,15].

Discussion of Procedures by Variant

Isolated Hematuria (nonpainful, nontraumatic)

Asymptomatic microscopic hematuria (usually defined as five or more red blood cells per high-powered field in either 2 or 3 of 3 consecutive urine specimens [16]) is a common entity, with an incidence estimated to be 0.25% to 1.0% in children 6 to 15 years of age [3-5,7-9,11,14,15].

Discussion of Procedures by Variant

Variant 1: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) without proteinuria. Initial imaging.

Patients without proteinuria or dysmorphic red blood cells (which indicate glomerular disease) are unlikely to have clinically significant renal disease, and no imaging is indicated [3,4,7,14,15]. Feld et al [3] evaluated 325 patients with microscopic hematuria; 87% had renal US and 24% had voiding cystoscopy urethrograms, and no findings were deemed to be clinically significant. Screening family members' urine may also be useful in the setting of persistent unexplained microhematuria, as benign familial hematuria, including thin basement membrane nephropathy, has been described [1,17,18]. Thin basement membrane nephropathy, an autosomal dominant condition, has been reported to be the most common cause of asymptomatic hematuria and usually has a benign course.

Variant 1: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) without proteinuria. Initial imaging.

A. CT

Computed tomography (CT) is not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria without proteinuria.

Variant 1: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) without

proteinuria. Initial imaging.
B. US

US is generally not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria without proteinuria.

Microscopic hematuria is sometimes associated with hypercalciuria [19] and hyperuricosuria, and some authors advocate renal US to evaluate for renal calculi in these patients [14,20], although others have found little value in this technique [3]. In cases of persistent unexplained microhematuria, US may be used to evaluate for occult anatomic abnormalities (cystic renal disease, nutcracker syndrome, congenital anomalies, etc), although the yield of these examinations is low [7-9,11,14,21]. Isolated microscopic hematuria is very rarely the presenting scenario of Wilms tumor [3].

Variant 1: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) without proteinuria. Initial imaging.
C. IVU

Intravenous urography (IVU) is not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria without proteinuria [14,21].

Variant 1: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) without proteinuria. Initial imaging.
D. MRI

Magnetic resonance imaging (MRI) is not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria without proteinuria.

Variant 1: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) without proteinuria. Initial imaging.
E. VCUG

VCUG is not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria without proteinuria.

Variant 1: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) without proteinuria. Initial imaging.
F. Voiding Urosonography

Voiding urosonography is not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria without proteinuria.

Variant 1: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) without proteinuria. Initial imaging.
G. Radiography

Radiography (abdomen and pelvis [KUB]) is not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria without proteinuria.

Variant 1: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) without proteinuria. Initial imaging.
H. Arteriography

Arteriography is not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria without proteinuria.

Variant 2: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) with

proteinuria. Initial imaging.

While protein and blood in the urine can be harmless in some children, patients with both microscopic hematuria and leakage of protein into the urine (with or without hypertension and edema) are more likely to have glomerular renal disease and eventually develop progressive chronic kidney disease [22]. Imaging findings are usually not specific for any underlying pathology.

Variant 2: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) with proteinuria. Initial imaging.
A. US

Kasap et al [23] showed that glomerulonephritis is a frequent cause of increased renal cortical echogenicity in childhood. The kidneys also may be enlarged in the setting of acute glomerulonephritis. In long-standing glomerular kidney disease, the kidneys may become atrophic with altered corticomedullary differentiation. Finally, US can help assess the feasibility of percutaneous kidney biopsy and aid in preprocedural planning.

Variant 2: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) with proteinuria. Initial imaging.
B. CT

CT is not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria with proteinuria.

Variant 2: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) with proteinuria. Initial imaging.
C. IVU

IVU is not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria with proteinuria.

Variant 2: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) with proteinuria. Initial imaging.
D. MRI

MRI is not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria with proteinuria.

Variant 2: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) with proteinuria. Initial imaging.
E. Radiography

Radiography (KUB) is not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria with proteinuria.

Variant 2: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) with proteinuria. Initial imaging.
F. VCUG

VCUG is not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria with proteinuria.

Variant 2: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) with proteinuria. Initial imaging.
G. Voiding Urosonography

Voiding urosonography is not appropriate in the initial evaluation of isolated nonpainful,

nontraumatic hematuria with proteinuria.

Variant 2: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) with proteinuria. Initial imaging.
H. IVU

IVU urography is not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria with proteinuria.

Variant 2: Child. Isolated microscopic hematuria (nonpainful, nontraumatic) with proteinuria. Initial imaging.
I. Arteriography

Arteriography is not appropriate in the initial evaluation of isolated nonpainful, nontraumatic hematuria with proteinuria.

Variant 3: Child. Isolated macroscopic hematuria (nonpainful, nontraumatic). Initial imaging.

Isolated asymptomatic macroscopic hematuria is usually due to benign processes such as hypercalcuria and IgA nephropathy [4,19,24-26]. Imaging has a role to exclude nephrolithiasis, underlying urologic abnormalities, and rarely renal or bladder tumors.

Variant 3: Child. Isolated macroscopic hematuria (nonpainful, nontraumatic). Initial imaging.
A. US

Renal and bladder tumors may present with gross hematuria and are likely to be found with US [4,14,27-29]. In addition to assessment of the kidneys, the child's urinary bladder should be examined during the US examination to assess for the presence of bladder lesions not diagnosed by the medical workup, such as polyps, masses, or vascular lesions [11]. The bladder should be distended with urine in order to optimize sonographic assessment. However, if unexplained hematuria persists in the absence of findings on US and there is concern for bladder urothelial neoplasm, cystoscopy may be indicated [30,31]. A renal or bladder mass that is detected by US may require further imaging with CT or MRI to define the local extent of disease or vascular invasion (in the case of Wilms tumor) and to detect the presence of any metastases [32]. Renal US is also an appropriate first-line imaging test for assessing children with suspected left renal vein obstruction (ie, nutcracker syndrome) [32].

Variant 3: Child. Isolated macroscopic hematuria (nonpainful, nontraumatic). Initial imaging.
B. VCUG

VCUG is usually not indicated in the evaluation of isolated macroscopic hematuria. A VCUG could be considered to evaluate for suspected posterior urethral valves in the male or other suspected urethral causes of hematuria, such as polyps, meatal stenosis, Cowper duct cyst, urethral stenosis, or an abnormality of the fossa navicularis.

Variant 3: Child. Isolated macroscopic hematuria (nonpainful, nontraumatic). Initial imaging.
C. Voiding Urosonography

While voiding urosonography is usually not indicated in the evaluation of isolated macroscopic hematuria, and there is a paucity of literature to support its use, it is likely that voiding urosonography also can be used to assess for causes of hematuria that may be detected by VCUG.

Variant 3: Child. Isolated macroscopic hematuria (nonpainful, nontraumatic). Initial imaging.
D. CT

CT is generally not indicated as a first-line test for isolated macroscopic hematuria. However,

contrast-enhanced CT has a role in evaluation of renal mass diagnosed by US, and it may be considered in children with recurrent macroscopic hematuria with negative US and extensive clinical workup in the rare setting of suspected left renal vein obstruction (ie, nutcracker syndrome) [33]. Unenhanced CT may also be used to evaluate for suspected asymptomatic nephrolithiasis as a cause of hematuria in the setting of a negative US.

Variant 3: Child. Isolated macroscopic hematuria (nonpainful, nontraumatic). Initial imaging. E. IVU

Because the incidence of upper urinary tract urothelial neoplasia is extremely rare in children, IVU is not indicated in the initial evaluation of isolated macroscopic hematuria [14,34].

Variant 3: Child. Isolated macroscopic hematuria (nonpainful, nontraumatic). Initial imaging. F. MRI

MR is generally not indicated as the first-line test for isolated macroscopic hematuria. In the cases of suspected renal mass or nutcracker syndrome, MRI may be of value for further diagnosis [25,27-29,33,35-41].

Variant 3: Child. Isolated macroscopic hematuria (nonpainful, nontraumatic). Initial imaging. G. Arteriography/Venography

Arteriography and venography have no role in the initial evaluation of isolated macroscopic hematuria.

Variant 3: Child. Isolated macroscopic hematuria (nonpainful, nontraumatic). Initial imaging. H. Radiography

Radiography (KUB) is generally not appropriate in the initial evaluation of isolated nonpainful, nontraumatic isolated macroscopic hematuria. Radiography may have a limited role for detecting suspected asymptomatic nephrolithiasis as a cause of hematuria.

Variant 4: Child. Painful hematuria (nontraumatic). Suspected urolithiasis. Initial imaging.

In the patient with abdominal pain and hematuria, the principal differential diagnosis is urolithiasis, although tumor and ureteropelvic junction (UPJ) obstruction should also be included. In young patients with genitourinary tract stone disease, the presenting symptoms may not be as classic as in adults, which in turn leads to uncertainty about the best imaging approach [42]. Interestingly, a number of pediatric patients with urolithiasis do not have hematuria [43]. While the incidence of pediatric stone disease is considerably lower than in adults, it is still commonly seen in busy pediatric practices [44]. Affected children may have a family history of nephrolithiasis or predisposing inborn metabolic disease [45,46]. While the literature provides general suggestions and guidelines, universal agreement regarding the imaging procedure of choice in suspected urolithiasis has not been reached.

Variant 4: Child. Painful hematuria (nontraumatic). Suspected urolithiasis. Initial imaging. A. CT

There is good evidence in adults that CT is the most accurate imaging modality in the identification of stones and the quantification of stone burden, with sensitivity and specificity both well above 90% [44,47-55]. With proper techniques and newer image iterative reconstruction algorithms, the CT dose can be very low and lowered to less than that of a traditional IVU [44,56,57]. Limitations of radiography (eg, small stone size, obscuration of stones by bowel contents) and US (eg, small stone size, obscuration of a portion of the kidney by bowel gas, poor sonographic window) in children do not impair CT evaluation. CT may be particularly useful in the setting of painful

hematuria, a negative kidney and bladder US examination, and high clinical suspicion for urolithiasis, particularly if detection would impact treatment.

Variant 4: Child. Painful hematuria (nontraumatic). Suspected urolithiasis. Initial imaging. B. US

US of the kidneys and bladder has limited sensitivity in detection of renal and ureteral stones. Palmer et al [49] reported that US found 75% of all urinary tract stones, although US found only 38% of stones within the ureter. Similarly, Oner et al [48] showed that US correctly found stones in 78% of patients, although it only found 25% of ureteral stones.

Stones typically appear as an echogenic focus with posterior acoustic shadowing; however, small stones may not have acoustic shadowing, especially when using newer US systems that are designed to minimize image artifacts. Ideally, any echogenic focus should be evaluated without spatial compounding as it decreases imaging artifacts, including posterior shadowing [58]. It is important to optimize imaging parameters, such as the use of harmonic imaging, as well.

The addition of color Doppler evaluation for "twinkling" artifact increases sensitivity of renal stone detection in the renal collecting system and visualized portions of the ureter, including at the ureterovesical junction [59-62]. A study by Masch et al [63] that included both adults and children found that twinkling artifact, in general, increases sensitivity, but decreases specificity. An isolated focus of sonographic twinkling has a sensitivity of 78%, but only has a specificity of 40% based on their study.

The same study by Masch et al [63] showed that US has a sensitivity of only 31% for renal stone detection if an echogenic focus, posterior acoustic shadowing, and twinkling artifact are all required findings to make a diagnosis. US is still recommended by some as a first-line screening test and, if positive, can then direct patient management [48,49,64], with the caveat that a negative US does not exclude stone disease [49].

Variant 4: Child. Painful hematuria (nontraumatic). Suspected urolithiasis. Initial imaging. C. Radiography

Levine et al [47] in a study of 178 adult and pediatric patients found radiographs had a 59% sensitivity for stone detection.

Variant 4: Child. Painful hematuria (nontraumatic). Suspected urolithiasis. Initial imaging. D. IVU

IVU is seldom indicated in children as an initial examination, although a limited study may provide information about stone position, degree of urinary tract obstruction, and movement after initial diagnosis.

Variant 4: Child. Painful hematuria (nontraumatic). Suspected urolithiasis. Initial imaging. E. MRI

MRI is not appropriate in the initial evaluation of painful hematuria and suspected urolithiasis.

Variant 4: Child. Painful hematuria (nontraumatic). Suspected urolithiasis. Initial imaging. F. VCUG

VCUG is not appropriate in the initial evaluation of painful hematuria and suspected urolithiasis.

Variant 4: Child. Painful hematuria (nontraumatic). Suspected urolithiasis. Initial imaging. G. Voiding Urosonography

Voiding urosonography is not appropriate in the initial evaluation of painful hematuria and suspected urolithiasis.

Variant 4: Child. Painful hematuria (nontraumatic). Suspected urolithiasis. Initial imaging. H. Arteriography

Renal arteriography is not appropriate in the evaluation of painful hematuria and suspected urolithiasis.

Traumatic Hematuria

Hematuria is frequently found in the pediatric patient with blunt abdominal trauma [65,66]. In children, the most commonly injured viscera are the spleen, liver, and kidney. The amount of hematuria that should trigger radiologic investigation of the urinary tract is somewhat controversial, but several facts are well accepted:

- Macroscopic (ie, gross) hematuria is a finding that necessitates a radiologic evaluation of the abdomen and pelvis [67-72]. In a study by Santucci et al [72] of 334 pediatric blunt trauma patients that underwent imaging, 59 renal injuries were identified in the setting of gross hematuria, shock, or history of significant deceleration.
- Isolated microscopic hematuria without any clinical or laboratory findings of visceral trauma or concerning mechanism of injury does not need emergency investigation [67,68,70-74]. In a study by Brown et al [67], pediatric patients with blunt trauma, microscopic hematuria, and no associated injuries were determined not to require radiologic evaluation, as significant renal injuries are unlikely in this setting. Another study by Perez-Brayfield et al [75] concluded that radiologic evaluation for renal injury is only indicated in the setting of blunt trauma when 50 or more red blood cells are present on urinalysis, when the patient is hypotensive upon presentation, or based on mechanism of injury.
- The presence of blood in the urethral meatus in a patient with pelvic fractures should lead to an investigation of the urethra and bladder (50% incidence of genitourinary injury) [76].
- Minor trauma to an anomalous kidney can cause major clinical repercussions (renal anomalies occur in 1% to 4% of the population) [68].
- All CT scans must be done with intravenous contrast (enhanced CT), unless specifically contraindicated.
- Hypotension is an unreliable clinical indicator for prompting imaging in children [70].
- If the abdominal and pelvic CT is used as the criterion standard for identifying urologic trauma in children, the microscopic urinalysis has moderate discriminatory power to predict urologic injury [77].

Variant 5: Child. Traumatic hematuria (macroscopic). Initial imaging.

Variant 5: Child. Traumatic hematuria (macroscopic). Initial imaging. A. CT (including CT cystography)

There is good evidence from multiple adult and pediatric studies that contrast-enhanced CT is the best modality for evaluating renal trauma, and that such imaging is required in patients with gross hematuria [67,68,70-73,78,79]. If renal injury is detected on CT, delayed scans should be obtained to evaluate for collecting system disruption [80].

Patients with gross hematuria and pelvic fractures are at high risk for bladder rupture [81,82]. The conventional fluoroscopic cystogram requires moving the patient to another imaging suite. There

is evidence that CT cystography (ie, CT of the pelvis performed after retrograde distention of the urinary bladder with iodinated contrast material) is an accurate method of evaluation, with the advantage that the patient need not be moved from the CT scanner [81-83]. Images are to be obtained with a contrast-filled bladder and may be obtained after drainage, although one study in adults suggests that postvoid images may be unnecessary [81]. Multiplanar reformatted images may help in diagnosis [84].

Variant 5: Child. Traumatic hematuria (macroscopic). Initial imaging.
B. Retrograde Urethrography

Patients with blood at the urethral meatus, especially if associated with pelvic fractures or straddle injury, are at risk for urethral injury and disruption. These patients should undergo retrograde urethrography prior to bladder catheter placement [76] and may warrant a cystogram to exclude concomitant bladder injury.

Variant 5: Child. Traumatic hematuria (macroscopic). Initial imaging.
C. US

While US has been advocated as a first-line imaging test in abdominal trauma, renal injuries are sometimes missed [85-87], and in the setting of gross hematuria these patients are better served with CT. A study by Mayor et al [88] documented a diagnostic accuracy of 41% for US when considering all types of renal injuries. Pilot studies on few post-traumatic patients suggest that contrast-enhanced US may increase sensitivity of US in detection of renal injuries. More studies are necessary to evaluate if contrast-enhanced US has any role in evaluation of renal injury [89,90]. Only a single US contrast agent has been approved for pediatric use in the United States as of this writing and would be used "off-label" in this setting.

Variant 5: Child. Traumatic hematuria (macroscopic). Initial imaging.
D. IVU

The limited or "one-shot" IVU was once a mainstay of adult renal trauma imaging. In current practice in a hemodynamically stable pediatric patient, the IVU has no role in the evaluation of hematuria [81].

Variant 5: Child. Traumatic hematuria (macroscopic). Initial imaging.
E. Radiography

In general, radiography is not appropriate in the initial evaluation of traumatic macroscopic hematuria. Radiographs of the pelvis may reveal pelvic fractures and, in the setting of macroscopic hematuria, raise the possibility of bladder or urethral injury.

Variant 5: Child. Traumatic hematuria (macroscopic). Initial imaging.
F. VCUG

VCUG is not appropriate for the initial evaluation of traumatic macroscopic hematuria. If there is concern for urethral injury, dedicated retrograde urethrography is a more appropriate initial imaging test. If there is concern for bladder injury, dedicated CT cystography is a more appropriate initial imaging test.

Variant 5: Child. Traumatic hematuria (macroscopic). Initial imaging.
G. Voiding Urosonography

Voiding urosonography is not appropriate for the initial evaluation of traumatic macroscopic hematuria. If there is concern for urethral injury, dedicated retrograde urethrography is a more appropriate initial imaging test. If there is concern for bladder injury, dedicated CT cystography is a

more appropriate initial imaging test.

Variant 5: Child. Traumatic hematuria (macroscopic). Initial imaging.
H. Arteriography

Arteriography is not appropriate in the initial evaluation of traumatic macroscopic hematuria. In the setting of hemodynamic instability and renal or pelvic artery extravasation detected by CT, arteriography may be used to guide endovascular embolization. Arteriography may also be used to guide the treatment of CT-detected post-traumatic pseudoaneurysms and arteriovenous fistulas [91,92].

Variant 5: Child. Traumatic hematuria (macroscopic). Initial imaging.
I. MRI

MRI is not appropriate in the initial evaluation of traumatic macroscopic hematuria.

Variant 6: Child. Traumatic hematuria (microscopic). Initial imaging.

Different threshold values have been used for evaluating post-traumatic microhematuria, but in general >50 RBC/hpf has been used as a threshold for imaging [75,93]. Recent studies note, at best, a fair correlation between degree of microhematuria and risk or severity of renal injury [67,70-72]. A study on patients ≥16 years old by Olthof et al [94] showed that although the presence of macroscopic hematuria (n = 16) led to clinical consequences in 73% of the patients, microscopic hematuria on urinalysis in combination with no findings on imaging led to clinical consequences in only 8 out of 212 patients (4%) and that microscopic hematuria on urinalysis in patients who did not undergo imaging for urogenital injury did not lead to clinical consequences (0 out of 54 patients; 0%). In children compared with adults, there is limited evidence and no consensus on the relationship between microscopic hematuria and renal trauma [71,79].

Variant 6: Child. Traumatic hematuria (microscopic). Initial imaging.
A. CT (including CT cystography)

Unlike in adults, no firm consensus has been reached on the best guidelines for imaging in pediatric blunt abdominopelvic trauma and microscopic hematuria [71,79]. For adult patients with isolated microscopic hematuria without coexistent injury, there is evidence that renal imaging with CT is unlikely to disclose clinically significant findings [67,70-72]. However, the evidence for that in children is limited. A study by Nguyen and Das [71] found that 12 of 32 (37.5%) with grades 2 to 5 renal injuries did not have macroscopic hematuria; 8 had microscopic hematuria, and 4 had normal urinalyses. Thus, the authors concluded that significant renal injuries can be encountered in the setting of microscopic hematuria, and the decision to perform CT should be based on history and mechanism of injury and not urinalysis alone. Children with congenital renal abnormalities (eg, UPJ obstruction), multiorgan injury, history of deceleration injury, localized flank pain, and ecchymosis should undergo CT imaging to evaluate for renal injury, even when gross hematuria is not present. Renal injury without macroscopic hematuria can also be found in a child with falling hemoglobin or a hemodynamic instability [70,72]. Microscopic hematuria has also been combined with other clinical variables to create prediction rules for identifying children with intra-abdominal injuries following blunt abdominal trauma [95].

Patients with hematuria, even microscopic, in the setting of pelvic fractures are at risk for bladder injury. Dedicated CT cystography is an accurate method of evaluation of bladder injury [81-83].

Variant 6: Child. Traumatic hematuria (microscopic). Initial imaging.
B. US

There is little evidence to support the use of US in the initial evaluation of traumatic microscopic hematuria. That said, renal US may be considered in cases of pediatric renal trauma that might otherwise not be imaged with CT because of low levels of hematuria to provide a screening tool for the occult vascular injury, pre-existing congenital anomaly, or the unusual major renal injury without significant hematuria.

Variant 6: Child. Traumatic hematuria (microscopic). Initial imaging.
C. Arteriography

Renal arteriography is not appropriate in the initial evaluation of traumatic microscopic hematuria.

Variant 6: Child. Traumatic hematuria (microscopic). Initial imaging.
D. Radiography

Radiography (KUB) is not appropriate in the initial evaluation of traumatic microscopic hematuria.

Variant 6: Child. Traumatic hematuria (microscopic). Initial imaging.
E. VCUG

VCUG is not appropriate in the initial evaluation of traumatic microscopic hematuria. If there is concern for urethral injury, dedicated retrograde urethrography is a more appropriate initial imaging test. If there is concern for bladder injury, dedicated CT cystography is a more appropriate initial imaging test.

Variant 6: Child. Traumatic hematuria (microscopic). Initial imaging.
F. Voiding Urosonography

Voiding urosonography is not appropriate in the initial evaluation of traumatic microscopic hematuria. If there is concern for urethral injury, dedicated retrograde urethrography is a more appropriate initial imaging test. If there is concern for bladder injury, dedicated CT cystography is a more appropriate initial imaging test.

Variant 6: Child. Traumatic hematuria (microscopic). Initial imaging.
G. Retrograde urethrography

Retrograde urethrography is not appropriate in the initial evaluation of traumatic microscopic hematuria, unless there is high clinical suspicion for urethral injury (eg, pelvic fractures or known straddle injury).

Variant 6: Child. Traumatic hematuria (microscopic). Initial imaging.
H. IVU

IVU is not appropriate in the initial evaluation of traumatic microscopic hematuria.

Variant 6: Child. Traumatic hematuria (microscopic). Initial imaging.
I. MRI

MRI is not appropriate in the initial evaluation of traumatic microscopic hematuria.

Summary of Highlights

- Imaging is usually not appropriate in the child initially presenting with nonpainful, nontraumatic isolated microscopic hematuria without proteinuria.
- US of the kidneys and bladder is usually appropriate in the child initially presenting with nonpainful, nontraumatic isolated microscopic hematuria with proteinuria.
- US of the kidneys and bladder is usually appropriate in the child initially presenting with

nonpainful, nontraumatic isolated macroscopic hematuria.

- Either US of the kidneys and bladder or CT of the abdomen and pelvis without IV contrast is usually appropriate in the child initially presenting with painful, nontraumatic hematuria and suspected urolithiasis.
- CT of the abdomen and pelvis with IV contrast is usually appropriate in the child presenting with macroscopic hematuria in the setting of trauma.
- CT of the abdomen and pelvis with IV contrast is usually appropriate in the child presenting with microscopic hematuria in the setting of trauma, particularly in the setting of congenital renal abnormalities (eg, UPJ obstruction), multiorgan injury, history of deceleration injury, localized flank pain, and flank ecchymosis.

Summary of Evidence

Of the 96 references cited in the *ACR Appropriateness Criteria® Hematuria-Child* document, 95 references are categorized as diagnostic references including 3 well-designed studies, 5 good-quality studies, and 23 quality studies that may have design limitations. There are 64 references that may not be useful as primary evidence. There is 1 reference that is a meta-analysis study.

The 96 references cited in the *ACR Appropriateness Criteria® Hematuria-Child[topic name]* document were published from 1987-2016.

Although there are references that report on studies with design limitations, 8 well-designed or good-quality studies provide good evidence.

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, please go to the ACR website at https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria.

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	5	The individual ratings are too dispersed from the

(Disagreement)		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.

Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	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 (e.g., 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. Kaneko K, Tanaka S, Hasui M, et al. A family with X-linked benign familial hematuria. Pediatr Nephrol. 2010; 25(3):545-548.
2. Kashtan CE. Familial hematuria. Pediatr Nephrol. 2009; 24(10):1951-1958.
3. Feld LG, Waz WR, Perez LM, Joseph DB. Hematuria. An integrated medical and surgical approach. Pediatr Clin North Am. 1997; 44(5):1191-1210.
4. Gordon C, Stapleton FB. Hematuria in adolescents. Adolesc Med Clin. 2005; 16(1):229-239.
5. Patel HP, Bissler JJ. Hematuria in children. Pediatr Clin North Am. 2001; 48(6):1519-1537.
6. Crop MJ, de Rijke YB, Verhagen PC, Cransberg K, Zietse R. Diagnostic value of urinary

dysmorphic erythrocytes in clinical practice. Nephron Clin Pract. 2010; 115(3):c203-212.

7. Benbassat J, Gergawi M, Offringa M, Drukker A. Symptomless microhaematuria in schoolchildren: causes for variable management strategies. Qjm .1996; 89(11):845-854.

8. Cilento BG, Jr., Stock JA, Kaplan GW. Hematuria in children. A practical approach. Urol Clin North Am. 1995; 22(1):43-55.

9. Fitzwater DS, Wyatt RJ. Hematuria. Pediatr Rev. 1994; 15(3):102-108; quiz 109.

10. Hisano S, Kwano M, Hatae K, et al. Asymptomatic isolated microhaematuria: natural history of 136 children. Pediatr Nephrol. 1991; 5(5):578-581.

11. Lieu TA, Grasmeder HM, 3rd, Kaplan BS. An approach to the evaluation and treatment of microscopic hematuria. Pediatr Clin North Am. 1991; 38(3):579-592.

12. Osegbe DN. Haematuria and sickle cell disease. A report of 12 cases and review of the literature. Trop Geogr Med. 1990; 42(1):22-27.

13. Tarry WF, Duckett JW, Jr., Snyder HM, 3rd. Urological complications of sickle cell disease in a pediatric population. J Urol. 1987; 138(3):592-594.

14. Meyers KE. Evaluation of hematuria in children. Urol Clin North Am. 2004;31(3):559-573.

15. Park YH, Choi JY, Chung HS, et al. Hematuria and proteinuria in a mass school urine screening test. Pediatr Nephrol. 2005; 20(8):1126-1130.

16. Diven SC, Travis LB. A practical primary care approach to hematuria in children. Pediatr Nephrol. 2000;14(1):65-72.

17. Blumenthal SS, Fritsche C, Lemann J, Jr. Establishing the diagnosis of benign familial hematuria. The importance of examining the urine sediment of family members. JAMA. 1988; 259(15):2263-2266.

18. Savige J, Rana K, Tonna S, Buzza M, Dagher H, Wang YY. Thin basement membrane nephropathy. Kidney Int. 2003; 64(4):1169-1178.

19. Bergstein J, Leiser J, Andreoli S. The clinical significance of asymptomatic gross and microscopic hematuria in children. Arch Pediatr Adolesc Med. 2005; 159(4):353-355.

20. Stapleton FB. Hematuria associated with hypercalciuria and hyperuricosuria: a practical approach. Pediatr Nephrol. 1994; 8(6):756-761.

21. Jequier S, Cramer B, Petitjeanroget T. Ultrasonographic screening of childhood hematuria. Can Assoc Radiol J. 1987; 38(3):170-176.

22. Zhai Y, Xu H, Shen Q, et al. Renal histological features of school-age children with asymptomatic haematuria and/or proteinuria: a multicenter study. Nephrology (Carlton). 2014;19(7):426-431.

23. Kasap B, Soylu A, Turkmen M, Kavukcu S. Relationship of increased renal cortical echogenicity with clinical and laboratory findings in pediatric renal disease. J Clin Ultrasound. 2006;34(7):339-342.

24. Greenfield SP, Williot P, Kaplan D. Gross hematuria in children: a ten-year review. Urology. 2007; 69(1):166-169.

25. Shin JI, Park JM, Lee JS, Kim MJ. Effect of renal Doppler ultrasound on the detection of nutcracker syndrome in children with hematuria. Eur J Pediatr. 2007; 166(5):399-404.

26. Youn T, Trachtman H, Gauthier B. Clinical spectrum of gross hematuria in pediatric patients. Clin Pediatr (Phila). 2006;45(2):135-141.

27. Gleason PE, Kramer SA. Genitourinary polyps in children. Urology. 1994; 44(1):106-109.

28. Lee CC, Lin JT, Deng HH, Lin ST. Hematuria due to nutcracker phenomenon of left renal vein: report of a case. J Formos Med Assoc. 1993; 92(3):291-293.

29. Takahashi Y, Akaishi K, Sano A, Kuroda Y. Intra-arterial digital subtraction angiography for children with idiopathic renal bleeding: a diagnosis of nutcracker phenomenon. Clin Nephrol. 1988; 30(3):134-140.

30. Lerena J, Krauel L, Garcia-Aparicio L, Vallasciani S, Sunol M, Rodo J. Transitional cell carcinoma of the bladder in children and adolescents: six-case series and review of the literature. J Pediatr Urol. 2010; 6(5):481-485.

31. Ander H, Donmez MI, Yitgin Y, et al. Urothelial carcinoma of the urinary bladder in pediatric patients: a long-term follow-up. Int Urol Nephrol. 2015;47(5):771-774.

32. Vianello FA, Mazzoni MB, Peeters GG, et al. Micro- and macroscopic hematuria caused by renal vein entrapment: systematic review of the literature. Pediatr Nephrol. 2016;31(2):175-184.

33. Fu WJ, Hong BF, Gao JP, et al. Nutcracker phenomenon: a new diagnostic method of multislice computed tomography angiography. Int J Urol. 2006; 13(7):870-873.

34. Mishra VC, Rowe E, Rao AR, et al. Role of i.v. urography in patients with haematuria. Scand J Urol Nephrol. 2004; 38(3):236-239.

35. Fitoz S, Ekim M, Ozcakar ZB, Elhan AH, Yalcinkaya F. Nutcracker syndrome in children: the role of upright position examination and superior mesenteric artery angle measurement in the diagnosis. J Ultrasound Med. 2007; 26(5):573-580.

36. Hogg RJ, Silva FG, Berry PL, Wenz JE. Glomerular lesions in adolescents with gross hematuria or the nephrotic syndrome. Report of the Southwest Pediatric Nephrology Study Group. Pediatr Nephrol. 1993; 7(1):27-31.

37. Shin JI, Park JM, Lee JS, Kim MJ. Doppler ultrasonographic indices in diagnosing nutcracker syndrome in children. Pediatr Nephrol. 2007; 22(3):409-413.

38. Shin JI, Park JM, Lee SM, et al. Factors affecting spontaneous resolution of hematuria in childhood nutcracker syndrome. Pediatr Nephrol. 2005; 20(5):609-613.

39. Alarcon CM, Cubillana PL, Aleman AC, Avellaneda EC. Hematuria secondary to congenital arteriovenous fistula treated with embolization. Arch Esp Urol. 2011; 64(6):550-553.

40. Ashley RA, Figueroa TE. Gross hematuria in a 3-year-old girl caused by a large isolated bladder hemangioma. Urology. 2010; 76(4):952-954.

41. Ben Abdallah Chabchoub R, Chabchoub K, Maaloul I, et al. [Nutcracker syndrome: a rare cause of hematuria]. Arch Pediatr. 2011; 18(11):1188-1190.

42. Polito C, La Manna A, Signoriello G, Marte A. Recurrent abdominal pain in childhood urolithiasis. Pediatrics. 2009; 124(6):e1088-1094.

43. Persaud AC, Stevenson MD, McMahon DR, Christopher NC. Pediatric urolithiasis: clinical predictors in the emergency department. Pediatrics. 2009; 124(3):888-894.

44. Strouse PJ, Bates DG, Bloom DA, Goodsitt MM. Non-contrast thin-section helical CT of

urinary tract calculi in children. Pediatr Radiol. 2002; 32(5):326-332.

45. Alpay H, Ozen A, Gokce I, Biyikli N. Clinical and metabolic features of urolithiasis and microlithiasis in children. Pediatr Nephrol. 2009; 24(11):2203-2209.

46. Cochat P, Pichault V, Bacchetta J, et al. Nephrolithiasis related to inborn metabolic diseases. Pediatr Nephrol. 2010; 25(3):415-424.

47. Levine JA, Neitlich J, Verga M, Dalrymple N, Smith RC. Ureteral calculi in patients with flank pain: correlation of plain radiography with unenhanced helical CT. Radiology 1997; 204(1):27-31.

48. Oner S, Oto A, Tekgul S, et al. Comparison of spiral CT and US in the evaluation of pediatric urolithiasis. Jbr-Btr. 2004; 87(5):219-223.

49. Palmer JS, Donaher ER, O'Riordan MA, Dell KM. Diagnosis of pediatric urolithiasis: role of ultrasound and computerized tomography. J Urol. 2005; 174(4 Pt 1):1413-1416.

50. O'Connor OJ, McSweeney SE, Maher MM. Imaging of hematuria. Radiol Clin North Am. 2008; 46(1):113-132, vii.

51. Potretzke AM, Monga M. Imaging modalities for urolithiasis: impact on management. Curr Opin Urol. 2008; 18(2):199-204.

52. Fielding JR, Steele G, Fox LA, Heller H, Loughlin KR. Spiral computerized tomography in the evaluation of acute flank pain: a replacement for excretory urography. J Urol. 1997;157(6):2071-2073.

53. Niemann T, Kollmann T, Bongartz G. Diagnostic performance of low-dose CT for the detection of urolithiasis: a meta-analysis. AJR Am J Roentgenol. 2008;191(2):396-401.

54. Poletti PA, Platon A, Rutschmann OT, Schmidlin FR, Iselin CE, Becker CD. Low-dose versus standard-dose CT protocol in patients with clinically suspected renal colic. AJR Am J Roentgenol. 2007;188(4):927-933.

55. Smith RC, Verga M, McCarthy S, Rosenfield AT. Diagnosis of acute flank pain: value of unenhanced helical CT. AJR Am J Roentgenol. 1996;166(1):97-101.

56. Karmazyn B, Frush DP, Applegate KE, Maxfield C, Cohen MD, Jones RP. CT with a computer-simulated dose reduction technique for detection of pediatric nephroureterolithiasis: comparison of standard and reduced radiation doses. AJR. 2009; 192(1):143-149.

57. Kulkarni NM, Uppot RN, Eisner BH, Sahani DV. Radiation Dose Reduction at Multidetector CT with Adaptive Statistical Iterative Reconstruction for Evaluation of Urolithiasis: How Low Can We Go? Radiology. 2012; 265(1):158-166.

58. Dunmire B, Harper JD, Cunitz BW, et al. Use of the Acoustic Shadow Width to Determine Kidney Stone Size with Ultrasound. J Urol. 195(1):171-7, 2016 Jan.

59. Lee JY, Kim SH, Cho JY, Han D. Color and power Doppler twinkling artifacts from urinary stones: clinical observations and phantom studies. AJR. 2001; 176(6):1441-1445.

60. Turrin A, Minola P, Costa F, Cerati L, Andrulli S, Trinchieri A. Diagnostic value of colour Doppler twinkling artefact in sites negative for stones on B mode renal sonography. Urol Res. 2007; 35(6):313-317.

61. Shabana W, Bude RO, Rubin JM. Comparison between color Doppler twinkling artifact and acoustic shadowing for renal calculus detection: an in vitro study. Ultrasound Med Biol.

2009; 35(2):339-350.

62. Dillman JR, Kappil M, Weadock WJ, et al. Sonographic twinkling artifact for renal calculus detection: correlation with CT. Radiology. 2011; 259(3):911-916.

63. Masch WR, Cohan RH, Ellis JH, Dillman JR, Rubin JM, Davenport MS. Clinical Effectiveness of Prospectively Reported Sonographic Twinkling Artifact for the Diagnosis of Renal Calculus in Patients Without Known Urolithiasis. AJR Am J Roentgenol. 206(2):326-31, 2016 Feb.

64. Johnson EK, Faerber GJ, Roberts WW, et al. Are stone protocol computed tomography scans mandatory for children with suspected urinary calculi? Urology. 2011; 78(3):662-666.

65. McAleer IM, Kaplan GW. Pediatric genitourinary trauma. Urol Clin North Am. 1995; 22(1):177-188.

66. Stalker HP, Kaufman RA, Stedje K. The significance of hematuria in children after blunt abdominal trauma. AJR. 1990; 154(3):569-571.

67. Brown SL, Haas C, Dinchman KH, Elder JS, Spirnak JP. Radiologic evaluation of pediatric blunt renal trauma in patients with microscopic hematuria. World J Surg. 2001; 25(12):1557-1560.

68. Chopra P, St-Vil D, Yazbeck S. Blunt renal trauma-blessing in disguise? J Pediatr Surg. 2002; 37(5):779-782.

69. Levy JB, Baskin LS, Ewalt DH, et al. Nonoperative management of blunt pediatric major renal trauma. Urology. 1993; 42(4):418-424.

70. Morey AF, Bruce JE, McAninch JW. Efficacy of radiographic imaging in pediatric blunt renal trauma. J Urol. 1996; 156(6):2014-2018.

71. Nguyen MM, Das S. Pediatric renal trauma. Urology. 2002; 59(5):762-766; discussion 766-767.

72. Santucci RA, Langenburg SE, Zachareas MJ. Traumatic hematuria in children can be evaluated as in adults. J Urol. 2004; 171(2 Pt 1):822-825.

73. Nance ML, Lutz N, Carr MC, Canning DA, Stafford PW. Blunt renal injuries in children can be managed nonoperatively: outcome in a consecutive series of patients. J Trauma. 2004; 57(3):474-478; discussion 478.

74. Taylor GA, Eichelberger MR, Potter BM. Hematuria. A marker of abdominal injury in children after blunt trauma. Ann Surg. 1988; 208(6):688-693.

75. Perez-Brayfield MR, Gatti JM, Smith EA, et al. Blunt traumatic hematuria in children. Is a simplified algorithm justified? J Urol. 2002; 167(6):2543-2546; discussion 2546-2547.

76. Abou-Jaoude WA, Sugarman JM, Fallat ME, Casale AJ. Indicators of genitourinary tract injury or anomaly in cases of pediatric blunt trauma. J Pediatr Surg. 1996; 31(1):86-89; discussion 90.

77. Thorp AW, Young TP, Brown L. Test characteristics of urinalysis to predict urologic injury in children. West J Emerg Med. 2011;12(2):168-172.

78. Rathaus V, Pomeranz A, Shapiro-Feinberg M, Zissin R. Isolated severe renal injuries after minimal blunt trauma to the upper abdomen and flank: CT findings. Emerg Radiol. 2004; 10(4):190-192.

79. Raz O, Haifler M, Copel L, et al. Use of adult criteria for slice imaging may limit unnecessary

radiation exposure in children presenting with hematuria and blunt abdominal trauma. Urology. 2011; 77(1):187-190.

80. Smith JK, Kenney PJ. Imaging of renal trauma. [Review] [58 refs]. Radiol Clin North Am. 41(5):1019-35, 2003 Sep.

81. Morgan DE, Nallamala LK, Kenney PJ, Mayo MS, Rue LW, 3rd. CT cystography: radiographic and clinical predictors of bladder rupture. AJR. 2000; 174(1):89-95.

82. Peng MY, Parisky YR, Cornwell EE, 3rd, Radin R, Bragin S. CT cystography versus conventional cystography in evaluation of bladder injury. AJR. 1999; 173(5):1269-1272.

83. Sivit CJ, Cutting JP, Eichelberger MR. CT diagnosis and localization of rupture of the bladder in children with blunt abdominal trauma: significance of contrast material extravasation in the pelvis. AJR. 1995; 164(5):1243-1246.

84. Chan DP, Abujudeh HH, Cushing GL, Novelline RA. CT cystography with multiplanar reformation for suspected bladder rupture: experience in 234 cases. AJR Am J Roentgenol. 2006 Nov;187(5):1296-302.

85. Filiatrault D, Longpre D, Patriquin H, et al. Investigation of childhood blunt abdominal trauma: a practical approach using ultrasound as the initial diagnostic modality. Pediatr Radiol. 1987; 17(5):373-379.

86. Korner M, Krotz MM, Degenhart C, Pfeifer KJ, Reiser MF, Linsenmaier U. Current Role of Emergency US in Patients with Major Trauma. Radiographics. 2008; 28(1):225-242.

87. Sirlin CB, Brown MA, Deutsch R, et al. Screening US for blunt abdominal trauma: objective predictors of false-negative findings and missed injuries. Radiology. 2003; 229(3):766-774.

88. Mayor B, Gudinchet F, Wicky S, Reinberg O, Schnyder P. Imaging evaluation of blunt renal trauma in children: diagnostic accuracy of intravenous pyelography and ultrasonography. Pediatr Radiol. 1995;25(3):214-218.

89. McGahan JP, Horton S, Gerscovich EO, et al. Appearance of solid organ injury with contrast-enhanced sonography in blunt abdominal trauma: preliminary experience. AJR Am J Roentgenol. 187(3):658-66, 2006 Sep.

90. Valentino M, Serra C, Pavlica P, et al. Blunt abdominal trauma: diagnostic performance of contrast-enhanced US in children--initial experience. Radiology. 2008; 246(3):903-909.

91. Halachmi S, Chait P, Hodapp J, et al. Renal pseudoaneurysm after blunt renal trauma in a pediatric patient: management by angiographic embolization. Urology. 2003;61(1):224.

92. Saad DF, Gow KW, Redd D, Rausbaum G, Wulkan ML. Renal artery pseudoaneurysm secondary to blunt trauma treated with microcoil embolization. J Pediatr Surg. 2005;40(11):e65-67.

93. Wu SR, Shakibai S, McGahan JP, Richards JR. Combined head and abdominal computed tomography for blunt trauma: which patients with minor head trauma benefit most? Emerg Radiol. 2006; 13(2):61-67.

94. Olthof DC, Joosse P, van der Vlies CH, de Reijke TM, Goslings JC. Routine urinalysis in patients with a blunt abdominal trauma mechanism is not valuable to detect urogenital injury. Emergency Medicine Journal. 32(2):119-23, 2015 Feb.

95. Holmes JF, Mao A, Awasthi S, McGahan JP, Wisner DH, Kuppermann N. Validation of a

prediction rule for the identification of children with intra-abdominal injuries after blunt torso trauma. Ann Emerg Med. 2009; 54(4):528-533.

96. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: https://edge.sitecorecloud.io/americancoldf5f-acrorgf92a-productioncb02-3650/media/ACR/Files/Clinical/Appropriateness-Criteria/ACR-Appropriateness-Criteria-Radiation-Dose-Assessment-Introduction.pdf.

Disclaimer

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.

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