

Evaluation of Gross Hematuria

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Screening healthy children for abnormalities in the urine has shown that microhematuria is common and often transient [1,2]. Evaluation of pediatric patients with persistent, isolated microhematuria is often not fruitful, and no identifiable cause is found in approximately 80% of cases. The most common cause identified is hypercalciuria (22%–30%) [3,4]. Even in these patients, the risk of an adverse outcome, such as urolithiasis, remains largely unknown. With demonstration of a low yield of significant and treatable disease, the cost-effectiveness of an extensive evaluation of asymptomatic microhematuria has been scrutinized [5–7]. This evaluation has led to many physicians questioning the routine practice of urinalysis screening in well children. Currently, the American Academy of Pediatrics recommends a screening urinalysis at 5 years of age, but only approximately half of pediatricians seem to follow this guideline [8,9]. When microhematuria is persistent, it is still considered imperative that a careful history and physical examination be performed to rule out organic causes. A family history positive for any renal disease, hearing loss, hematuria, or dialysis and transplantation also should be regarded as possible important clues to disease. The primary physician should continue to follow patients carefully and watch for the development of any new symptoms or urinary findings and consider re-evaluation.

Physicians who provide care to adults and children must be aware that adult patients who have microhematuria require more investigation, because only 8% to 10% of patients have no identifiable cause. The proper evaluation in adults has been reviewed carefully. Guidelines have been developed that offer a strategic approach to this common problem. The biggest threat is urothelial cancers, which are carefully screened for in each patient [10,11].

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Gross hematuria, or macroscopic hematuria, is defined as blood that can be seen with the naked eye. Parents and patients are often distraught when it presents and seek medical care immediately. It is a common complaint in children. In one pediatric center, it accounted for 1.3 cases in 1000 urgent visits [12]. In contrast to microhematuria, systematic evaluation of gross hematuria often bears results, and most patients have a clinically important cause identified [3,12,13]. The reader is referred elsewhere for an in-depth comprehensive review and a practical approach to microhematuria in children [7,14,15]. This article is devoted to the evaluation of common and uncommon causes of gross hematuria in infants and children.

Approach to the evaluation of gross hematuria

There are many causes of urinary tract bleeding. The source of bleeding can originate from the glomerulus and interstitium, the urinary tract, or renal vasculature. **Box 1** lists common and uncommon causes of gross hematuria in children.

When a patient complains of gross hematuria, one should ask specific details that offer clues to the cause of the hematuria. The description of the urine should be specific. The urine color may give clues as to the severity and the source of bleeding. “Pink-tinged” urine denotes a much smaller amount of blood and is rarely seen in glomerular disease. In patients who have glomerular disease, the urine is uniformly discolored, without clots, and can be a deep, brownish-red color or dark brown, like “tea” or “coca-cola.” Patients who have vascular bleeding or lower urinary tract bleeding often describe the urine as bright red or cherry-colored, and if the bleeding is severe enough it can be a dark, opaque burgundy color. Likewise, patients may describe the urine as actually yellow but with blood unevenly mixed with the urine or perhaps with blood clots, both of which denote a nonglomerular source of bleeding such as in the lower urinary tract. Patients might report urinary bleeding that only appears at the initiation of a void or at the end of a void, which gives clues to either urethritis or cystitis (or trigonitis), respectively [16].

One must be aware that not all discolored or dark urine is necessarily from blood. Pediatricians are familiar with the pink diaper syndrome in newborns, a benign phenomenon in which a red-brown spot of urine in the diaper is caused by urate crystals. Many substances discolor urine, such as pigments (eg, hemoglobin, myoglobin), food substances (eg, beets, blackberries), drugs (eg, rifampin, pyridium, nitrofurantoin, metronidazole), and organic biochemicals (eg, porphyrins, methemoglobin) [15].

Symptoms

Ascertaining whether pain is associated with gross hematuria is important. One should suspect urolithiasis in patients who have episodic flank pain, severe

Box 1. Causes of gross hematuria in children*Glomerular**Primary*

Acute poststreptococcal glomerulonephritis
IgA nephropathy*
Mesangial proliferative glomerulonephritis
Membrano proliferative glomerulonephritis
Alport syndrome
Thin basement membrane disease/benign familial hematuria
Rapidly progressive glomerulonephritis

Systemic

Henoch-Schönlein purpura
Systemic lupus erythematosus
Hemolytic uremic syndrome/thrombotic
thrombocytopenic purpura
Wegener granulomatosis
Goodpasture's disease
Bacterial endocarditis
Microangiopathic polyarteritis nodosa

Other

Idiopathic hypercalciuria without urolithiasis*
Polycystic kidney disease (autosomal dominant)

Interstitial disease

Pyelonephritis
Acute interstitial nephritis
Tubulointerstitial nephritis with uveitis

Vascular

Trauma
Sickle cell disease and trait
Renal artery/vein thrombosis
Arteriovenous thrombosis
Nutcracker syndrome
Malignant hypertension
Sports- and exercise-related hematuria
Hemangioma/hamartoma

Neoplastic

Wilms' tumor
Renal cell carcinoma
Uroepithelial tumors
Rhabdoid tumors
Congenital mesoblastic tumor
Angiomyolipoma

Urinary tract

Cystitis
Bacterial
Viral (adenovirus)
Parasitic (schistosomiasis)
Tuberculosis
Urethritis
Urolithiasis
Idiopathic hypercalciuria
Trauma
Severe hydronephrosis
Foreign body
Cyclophosphamide cystitis

Bleeding disorders

Hemophilia A or B
Platelet disorder
Thrombocytopenia
Coagulopathy, congenital or acquired

* Common cause of asymptomatic gross hematuria.

abdominal pain, or dysuria. Patients with fever and pain may have a urinary tract infection, although gross hematuria is an uncommon symptom of bacterial urinary tract infection in children. Urinary tract obstruction, such as in ureteropelvic obstruction, may remain occult until infection, trauma, or bleeding occurs as a complication. Bleeding from renal tumors is uncommon but should be considered, especially if accompanied by abdominal pain or a mass. Gross hematuria caused by glomerular disease is rarely accompanied by significant pain, although some patients may report mild flank discomfort. An exception is Henoch-Schönlein purpura, a common pediatric systemic vasculitis with severe gastro-

intestinal disease. Irritative symptoms, such as dysuria, urgency, and frequency, can be seen in bleeding from the bladder.

Clues to glomerular disease may be a history of recent pharyngitis, streptococcal skin infection, or other febrile illnesses, which indicate possible acute postinfectious glomerulonephritis. Patients who have glomerulonephritis or renal insufficiency may report shortness of breath, edema, or weight gain from fluid retention. Abdominal pain, diarrhea, hematochezia, joint pains, rash, and arthralgias are symptoms of a systemic vasculitis such as Henoch-Schönlein purpura. Recurrent, painless gross hematuria is often seen in young patients with IgA nephropathy in association with concurrent respiratory illness. Fevers, weight loss, alopecia, mouth ulcers, chest pain, fatigue, and arthritis suggest systemic lupus erythematosus. Hemoptysis or cough is seen in rare pulmonary-renal syndromes, such as Goodpasture's syndrome and Wegener granulomatosis.

Other history

Activities that exacerbate the gross hematuria should be ascertained. Gross hematuria has been reported in patients who perform extreme exercise, such as marathon running [17]. In infants with gross hematuria, birth asphyxia or use of umbilical catheters may indicate a renal vascular thrombosis [18]. African American patients should be asked for a history of sickle cell hemoglobinopathy, because gross hematuria is reported in persons with sickle cell trait disease. A medication history should be obtained carefully because drug-induced interstitial nephritis is a complication seen with several classes of medications, including antibiotics, anticonvulsants, and nonsteroidal anti-inflammatory drugs, the last of which also can cause papillary necrosis. Cyclophosphamide administration can cause a severe hemorrhagic cystitis. A history of other occurrences of frequent bleeding, such as heavy menses, prolonged nosebleeds, hemarthroses, and bleeding associated with surgical procedures, might indicate an undiagnosed bleeding disorder. Exposure history to tuberculosis should be obtained, as should a travel history, because parasitic infections such as schistosomiasis of the bladder are common in other parts of the world. Questions specific to other sources of bleeding include those directed at foreign body, trauma, sexual abuse, and menstruation.

Family history

Ascertaining a family history of kidney disease that led to end-stage renal failure is important because Alport syndrome, commonly an X-linked disorder, may cause only hematuria in childhood, although more often it is microscopic. Benign familial hematuria and familial thin basement membrane disease are also responsible for microhematuria and gross hematuria. The genetics of thin basement membrane disease recently were elucidated, and mutations have been

identified that are identical to those seen in some autosomal recessive forms of Alport syndrome. Patients who have thin basement membrane disease may be carriers of autosomal recessive Alport syndrome [19]. Patients who have autosomal dominant polycystic kidney disease also may develop spontaneous bleeding into the macrocysts, which causes gross hematuria and pain. Gross hematuria is a presenting complaint in 15% children with urolithiasis [20]. Kidney stone disease can be familial and, in some cases, related to specific genes, as in X-linked nephrolithiasis or Dent's disease. A history of other genetic diseases, such as hemophilia, platelet disorders, or sickle cell disease, should be sought.

Physical examination

The physician should perform a careful examination of the abdomen to look for abdominal or flank masses. The most common renal tumor seen in young children (aged 1–4 years) is Wilms' tumor, although other types do occur [21]. Hydronephrosis or enlarged cystic kidneys may be palpable. Suprapubic pain may isolate the source of bleeding and indicate possible infection, stone, or other bladder pathology. Blood pressure measurement should be performed to look for hypertension and may indicate glomerulonephritis or renal insufficiency, especially in the presence of edema. Growth should be assessed. Failure to thrive may indicate a chronic renal disease. Presence of pallor, fever, skin rashes or musculoskeletal findings may give clues to systemic disease, such as systemic lupus erythematosus with glomerulonephritis. As the history or symptoms dictate, the genitalia should be inspected for a foreign body or tears and lacerations caused by abuse or accidents.

Evaluation

Laboratory tests

Microscopic examination of the urine should be performed to confirm the presence of red blood cells. If absent, myoglobinuria, hemoglobinuria, or other substances (eg, medications or food substances) should be considered. Plasma proteins are excreted in proportion to the degree of bleeding, and gross hematuria from lower urinary tract bleeding often only gives rise to <2 + proteinuria by dipstick reading. Anything more than 2 + protein should raise suspicion of glomerular disease. Hemolysis of urinary erythrocytes may occur and result in >2 + proteinuria, but the supernatant of spun urine is a pinkish color with free hemoglobin [16]. Red cell casts observed on a resuspended pellet of spun urine (centrifuged 5 minutes at 1500–2000 rpm) under high power field may be a clue to glomerulonephritis. Bacteria and significant pyuria may indicate pyelonephritis or cystitis.

Further inspection of the erythrocyte morphology may provide insight into the origin of the bleeding. Size, shape, and hemoglobin content can help differentiate the source of erythrocytes. Small, dysmorphic, or crenated cells with low hemoglobin content (pale cells) are believed to originate from the glomerulus, whereas normal-shaped and -sized cells originate from the urinary tract outside the glomerulus. This examination is best done with a phase contrast microscope. The availability of this technique in most clinical settings is limited, and its ability to predict more accurately the source of bleeding in children has been questioned [22]. Quantification of gross hematuria is possible by obtaining a “urocit”; a result $> 1\%$ is often an indication of lower tract bleeding [16].

Additional laboratory testing is dictated by the suspected source of bleeding and patient symptoms and history. All patients with suspected glomerulonephritis should have an assessment of their renal function (serum creatinine) and a complete blood count. Degree of proteinuria can be assessed with a 24-hour urine collection or with a spot urine protein:creatinine ratio [23]. Serologic studies to investigate immune-mediated glomerulonephritis should be performed and include complement levels (C3, C4), antinuclear antibody, and anti-double-stranded DNA antibody. Antineutrophilic cytoplasmic antibody titers and antiglomerular basement antibody titers should be obtained if vasculitis or pulmonary-renal syndromes are suspected. The diagnosis of most cases of postinfectious glomerulonephritis can be made clinically; however, a kidney biopsy is often needed to determine other forms. Even if serologic diagnosis of vasculitis is made, staging of the severity of renal disease with renal pathology, such as in systemic lupus erythematosus, is important for determining therapies. The diagnosis of Henoch-Schönlein Purpura (HSP) is also made clinically; however, skin biopsy of purpuric lesions that demonstrate vasculitis and presence of predominantly IgA deposits can be supportive evidence. If HSP presents with significant proteinuria or renal insufficiency, a renal biopsy is performed to assess for severity and make a definitive diagnosis (Table 1).

A urine culture is indicated in patients who have fever, flank pain, or abdominal and bladder pain. Gross hematuria also can be seen with nonbacterial infections, such as tuberculosis, adenovirus, and schistosomiasis [24,25].

Hypercalciuria is a common cause of microhematuria and it can lead to gross hematuria [4]. This metabolic disease is characterized by excessive calcium excretion in the urine in the absence of hypercalcemia or other known causes of hypercalciuria. The hematuria is believed to be secondary to calcium oxalate and phosphate crystals adhering to uroendothelium. The risk of developing kidney stones is not known, but it may be increased in patients who have gross hematuria [26,27]. Although it often produces no symptoms, hypercalciuria is also implicated in urinary symptoms and abdominal and flank pain.

Hypercalciuria is defined by a 24-hour urine for calcium excretion > 4 mg/kg/d or a spot urine calcium:creatinine ratio of > 0.22 , although the normal values may be greater in children younger than 7 years of age [28]. Calyceal micro-lithiasis is an ultrasonographic finding in hypercalciuria, although the clinical significance regarding future stone formation seems small but deserving of ob-

Table 1
Laboratory testing in suspected glomerulonephritis (GN) *

Symptoms	Suspected glomerulonephritis	Laboratory
History of pharyngitis, impetigo	Acute poststreptococcal GN	C3, C4, ASO, Anti-Dnase B
Arthralgia, purpura, pedal edema, abdominal pain, hematochezia	Henoch-Schönlein purpura	Skin biopsy
Arthritis, rash, fever, oral ulcers weight loss, alopecia, weakness, central nervous system symptoms	Systemic lupus erythematosus	C3, C4, ANA, anti-ds DNA
Family history of renal failure, hearing loss, hematuria	Alport syndrome	Audiogram, slit lamp examination
Recurrent, painless gross hematuria	IgA nephropathy	Serum IgA
Hemoptysis, cough, fevers	Goodpasture's syndrome	Anti-GBM Ab
Rash, sinus disease, hemoptysis	Wegener's granulomatosis	ANCA
Medication exposure (antibiotics, anticonvulsants, NSAIDs)	Acute interstitial nephritis	Urine eosinophils

Abbreviations: ANA, antinuclear antibody; ANCA, antineutrophilic cytoplasmic antibody; anti-Dnase, anti-deoxyribonuclease antibody; anti-ds (native) DNA, anti-double-stranded DNA antibody; anti-GBM, antiglomerular basement antibody; ASO, antistreptolysin O antibody; GN, glomerulonephritis NSAIDs, nonsteroidal anti-inflammatory drugs.

* All patients: serum creatinine, complete blood count, electrolytes, 24-hour urine collection for protein, random urine protein:creatinine ratio.

servation [26]. There seems to be an association of thin basement membrane disease with hypercalciuria, the pathophysiology of which remains unexplained [29].

Radiologic imaging and cystoscopy

Renal imaging with noninvasive ultrasonography is recommended to investigate urologic disease or congenital abnormalities but also can give substantive evidence for renal parenchymal disease. Enlarged, echogenic kidneys with poor corticomedullary differentiation and normal contour provide evidence for glomerular or interstitial nephritis. Nephrolithiasis or calcinosis is seen on ultrasound, as is hydronephrosis secondary to urinary obstruction from lower tract kidney stones.

Cystograms generally play no major role in the evaluation of gross hematuria unless there is suspicion of bladder outlet obstruction from an unusual mass, such as a urothelial tumor, rhabdomyosarcoma, or fibromatous polyp [30,31]. In these cases, cystoscopy is often definitive in diagnosing bladder sources of

bleeding and provides an opportunity to obtain tissue for diagnosis. Cystoscopy also may be helpful in looking for unilateral bleeding from one ureter or diagnosing more uncommon lesions, such as hemangiomas of the bladder.

CT imaging is used to identify kidney stones (using helical technique) and provides detailed images of the bladder, pelvis, and retroperitoneum when looking for masses. Angiogram of the kidney may be necessary if looking for unusual arteriovenous malformations of the kidney.

Common causes of asymptomatic gross hematuria

One of the most perplexing problems is when gross hematuria presents in the absence of any symptoms. In these cases, the lack of systemic symptoms or any pain provides a diagnostic challenge as to where to begin the evaluation. Although less commonly found, all patients should first have radiologic interrogation to rule out renal and bladder tumors. In one study of asymptomatic patients, 62% had an identifiable cause [3]. The most common cause detected was hypercalciuria without nephrolithiasis (22%).

Recurrent episodes of painless, gross hematuria are a common presentation in childhood IgA nephropathy. This form of glomerulonephritis is common in children and adults, with the mean age of presentation in children being 9 to 10 years. Episodes of gross hematuria are triggered by concurrent upper respiratory illnesses followed by complete resolution of gross hematuria and sustained microhematuria. Patients also can develop acute nephritic symptoms, acute renal failure, or nephrotic syndrome. Serum complement is normal and IgA levels are elevated in only 8% to 16% of children. Diagnosis is made by renal biopsy showing mesangial proliferation and glomerular deposition of IgA immune deposits.

Acute postinfectious glomerulonephritis is the most common form of glomerulonephritis in children, and it is not unusual for it to be asymptomatic. It accounts for 11% of all patients with gross hematuria referred to a specialty clinic [3]. Hypertension is not necessarily present and, when present, can be asymptomatic, especially in milder cases.

Unusual causes of gross hematuria

Sports- or exercise-related causes

Gross hematuria can occur after workouts of high intensity and long duration and may not occur until a young athlete is at a competitive level. Its pathophysiology is not known, but several mechanisms proposed include bladder or kidney trauma, hemolysis, dehydration, peroxidation of red cells, and renal ischemia [32].

Hemangiomas

Bladder hemangiomas or hamartomas should be considered when urinary tract bleeding is present in patients who have conditions such as Klippel-Trenaunay syndrome and Proteus syndrome, two rare hamartomatous disorders. Use of endoscopic laser treatment on bladder lesions has been reported [33,34].

Nutcracker syndrome

This syndrome occurs when the left renal vein is compressed between the superior mesenteric artery and aorta, which causes a rise in pressure and development of collateral veins (venous varicosities of the renal pelvis, ureter, and gonadal vein). It presents with left flank pain, unilateral hematuria, and occasionally a varicocele in male patients. Diagnosis can be difficult, but Doppler studies of the left renal vein, magnetic resonance angiography, and CT have been applied [35].

Unusual infections

Bladder lesions with *Schistosoma haematobium* contain eggs and a surrounding granuloma. Urinary symptoms are common, such as suprapubic pain, dysuria, and urgency. Chronic inflammation of the ureters may result in urinary obstruction. Diagnosis is made by biopsy of the liver, rectum, or bladder or by detection of eggs in feces and urine.

Mycobacterium tuberculosis is observed in global communities and continues to be a growing problem. Renal involvement can occur and result in formation of tuberculomata that cavitate and possibly rupture and disseminate the bacterium throughout the urinary tract. Tuberculosis of the genitourinary tract most often occurs in young adults and is characterized by tubercles observed at the ureteral orifices [36].

Adenovirus, a common respiratory virus in children, causes hemorrhagic cystitis. This complication occurs most often in immunocompromised patients, although it also can affect normal, healthy children [24].

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