Increased Renal Parenchymal Echogenicity: Causes in Pediatric Patients

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The authors discuss some of the diseases that cause increased echogenicity of the renal parenchyma on sonograms in children. The illustrated cases include patients with more common diseases, such as nephrotic syndrome and glomerulonephritis, and those with rarer diseases, such as oculocerebrorenal syndrome. Hyperechogenicity is a nonspecific finding but a significant one in that it suggests the presence of renal abnormalities. When it is demonstrated, further investigation is usually warranted.

Introduction
The ultrasound (US) finding of increased echogenicity of the renal parenchyma in children usually indicates parenchymal disease. However, hyperechogenicity is a nonspecific finding because no definite correlation exists between the sonographic appearance of the kidney and the renal pathologic condition (1). The pathologic basis for increased echogenicity is often obscure; is probably complex; and may involve glomerular, tubular, interstitial, or vascular abnormalities (2,3).

Many diseases cause an abnormal increase in renal parenchymal echogenicity (4). Some of the more common causes are listed in Table 1, which also matches the disease to kidney size on the basis of our observations and reports in the literature. This article discusses some common and some unusual diseases that cause hyperechogenicity. For the diseases described, pathologic bases for hyperechogenicity will be mentioned when they are known.

Abbreviation: PAS = periodic acid Schiff

Index terms: Glycogen storage disease, 81.59 • Hemolytic-uremic syndrome, 81.69 • Kidney, diseases, 81.144, 81.59, 81.60, 81.697 • Kidney, US studies, 811.1298 • Kidney neoplasms, 81.34 • Lymphoma, 81.34 • Oxalosis, 81.59 • Sickle cell disease (SS, SC), 81.651 • Ultrasound (US), in infants and children, 811.1298


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Figures 1, 2. (1) Sonogram in a healthy 25-day-old infant demonstrates normal renal cortical echogenicity, which is equal to that of the liver. (2) Sonogram of a healthy 4-year-old boy shows renal cortical echogenicity that is less than that of the liver.

- NORMAL APPEARANCE
The echogenicity of the renal cortex is best assessed by comparing it with that of the adjacent liver or spleen. Normally, the echogenicity of the renal cortex is less than that of the adjacent organs (5). However, in neonates and infants up to 6 months of age, the echogenicity may be equal to that of the liver or spleen (Figs 1, 2). This disparity has been attributed to variation in glomerular volume and distribution (6,7).

- DISEASES CAUSING HYPERECHOGENICITY

- Nephrotic Syndrome
Nephrotic syndrome is a symptom complex characterized by proteinuria, hypoproteinemia, edema, and hyperlipidemia. Clinically, the syndrome is the manifestation of numerous distinct glomerular disorders, of which approximately 90% result from primary glomerular disease (idiopathic) and 10% are secondary to systemic disease (8). The basic pathologic abnormality is an increase in permeability in the capillaries of the glomerular wall. This abnormality causes proteinuria.

Idiopathic nephrotic syndrome occurs in three morphologic patterns: (a) minimal change (85% of patients), (b) mesangial cell proliferation (5%), and (c) focal sclerosis (10%). They differ in the degree of mesangial cell and matrix proliferation (9).

Sonograms obtained in patients with nephrotic syndrome may show a large kidney with a nonspecific increase in parenchymal echogenicity (Figs 3, 4). However, the morphologic patterns of the syndrome cannot be distinguished with US.

- Glomerulonephritis
Glomerulonephritis is usually the result of immunologic injury to the kidney associated with deposition of immune complexes in glomerular structures (10). The US appearance of the kidneys in patients with glomerulonephritis is variable, regardless of the cause of the disease. In acute glomerulonephritis, the kidneys may be normal or enlarged, while small echogenic kidneys may be seen in chronic disease. The most common form found in children is poststreptococcal glomerulonephritis. Other less common types include membranous glomerulonephritis, membranoproliferative disease,
Figures 3, 4. (3) Sonogram of a 3-year-old girl with nephrotic syndrome shows nonspecific increase in echogenicity. Focal glomerulosclerosis was seen at biopsy. (4a) Sonogram of 3-year-old boy with steroid-resistant nephrotic syndrome shows a large kidney with increased echogenicity and absence of corticomedullary differentiation. (4b) High-power photomicrograph (original magnification, X200; periodic acid–Schiff [PAS] stain) of renal biopsy specimen shows an increase in mesangial matrix and focal mesangial cell hyperplasia (arrows). Immunofluorescent studies (not shown) revealed granular immunoglobulin M deposition in mesangial cells. These findings are characteristic of immunoglobulin M mesangiopathy, a form of steroid-resistant nephrotic syndrome.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Diseases That Cause Increased Renal Parenchymal Echogenicity</th>
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<tbody>
<tr>
<td>Diagnosis</td>
<td>Kidney Size</td>
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<td></td>
<td>Small</td>
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<tr>
<td>Nephrotic syndrome</td>
<td>X</td>
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<tr>
<td>Glomerulonephritis (acute)</td>
<td>X</td>
</tr>
<tr>
<td>Glycogen storage disease</td>
<td>X</td>
</tr>
<tr>
<td>Hemolytic uremic syndrome</td>
<td>X</td>
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<tr>
<td>Polycystic kidney disease</td>
<td>X</td>
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<tr>
<td>Lymphoma</td>
<td>X</td>
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<td>Acute pyelonephritis</td>
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<td>Sickle cell anemia</td>
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<td>Renal dysplasia</td>
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<td>Chronic renal failure</td>
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<td>Acquired immunodeficiency synde</td>
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Figures 5, 6.  (5a) Sonogram of an 8-month-old girl with membranoproliferative glomerulonephritis shows a normal-sized echogenic kidney.  (5b) High-power photomicrograph (original magnification, ×200; PAS stain) of renal biopsy specimen shows lobular accentuation of glomerular segments, with proliferation of glomerular mesangial cells and extension of those cells into the capillary loops. These findings are characteristic of membranoproliferative glomerulonephritis. (5c) Another high-power view (original magnification, ×200; silver and PAS stain) of the glomerular tuft shows capillary basement membrane splitting (arrows) due to the interposition of the mesangial cells. (6) Sonogram of a 9-year-old boy with immunoglobulin A nephropathy, a form of glomerulonephritis characterized by the predominance of immunoglobulin A in the mesangial deposits. The kidney is enlarged and has increased parenchymal echogenicity.
and glomerulonephritis secondary to systemic lupus erythematosus and chronic infection (Figs 5, 6).

- **Glycogen Storage Disease**
  The glycogen storage diseases are inherited metabolic errors causing either abnormal glycogen concentrations or glycogen structure. Of the six types, type 1 or Von Gierke disease is the most common. It results from a deficiency of glucose-6-phosphatase, an enzyme that mobilizes glycogen in the cells of the liver, kidney, and intestinal mucosa. Without this enzyme, glycogen accumulates in these tissues and they subsequently enlarge. Nephromegaly is seen only in type 1 disease (11). Clinical characteristics include growth retardation, hyperlipidemia, and hypoglycemia.

  US of the kidneys demonstrates renal enlargement. In some patients, increased echogenicity in the renal cortex is also observed on sonograms (Fig 7) (4).

- **Hemolytic Uremic Syndrome**
  Hemolytic uremic syndrome is a microangiopathic hemolytic anemia that causes thrombocytopenia, renal failure, and hypertension (12). It is thought to result from endothelial damage to the renal cortical vasculature, possibly from an endotoxin. Clinically, patients may present with fever, vomiting, diarrhea, and abdominal pain. Despite the severity of the illness, most patients recover completely.

  Initially, the sonographic findings in patients with hemolytic uremic syndrome may be normal, or nephromegaly may be seen. With more severe involvement, US demonstrates increased renal cortical echogenicity (Fig 8) (13,14). The hyperechogenicity is probably related to swelling of glomerular endothelial and mesangial cells, as well as to the presence of platelet aggregates and fibrin thrombi in the lumina of glomerular capillaries (12).

**Figures 7, 8.** (7) Sonogram of an 11-year-old patient with type 1 glycogen storage disease shows an enlarged kidney and increased renal parenchymal echogenicity. Some medullary pyramids are seen as relatively hypoechoic structures. (8) Sonogram of a 4-year-old boy with hemolytic uremic syndrome demonstrates a diffuse increase in cortical echogenicity in the right kidney. The boy presented with vomiting, diarrhea, and hematuria. His blood urea nitrogen level was 70 mg/100 mL; creatinine level, 3.4 mg/dL (300.6 μmol/L); hemoglobin mass concentration, 9.5 g/dL (95 g/L); and platelet count, 67,000.
Figure 9. (a) Sonogram of a 5-year-old girl with infantile polycystic kidney disease demonstrates large, echogenic kidneys that lack normal architecture. (b) Longitudinal sonogram of her 3-year-old brother shows upper pole of the right kidney (open arrows) and adjacent liver. Both the kidney and the liver are echogenic. Solid arrow indicates a 2-cm cyst in the liver.

Figure 10. Longitudinal (a) and transverse (b) sonograms of the right kidney in a 17-year-old boy with Burkitt lymphoma. The kidney is very large (18 cm in length) and shows a patchy but diffuse increase in echogenicity. The left kidney showed similar findings.
• Infantile Polycystic Kidney Disease

Most cases of infantile polycystic kidney disease are autosomal recessive, but the autosomal dominant form may be manifested in infancy as well. The disease is associated with a spectrum of pathologic changes involving both the kidneys and liver, including bilateral renal enlargement. The kidneys contain innumerable microscopic cortical and medullary cysts representing dilated distal tubules and collecting ducts (15). Cysts may also be seen in the liver, spleen, and pancreas, usually in patients with the dominant form of the disease. The classic liver abnormality of the recessive form is periporal fibrosis (Fig 9).

The cysts characteristic of this disease provide acoustical interfaces that cause increased echogenicity and poor corticomedullary differentiation on US images (16). When present in young children, the adult type of polycystic kidney disease can be similar in appearance to the infantile variety.

• Lymphoma

The kidneys are the most frequent extranodal site of metastases from lymphoma. Renal involvement occurs most often in non-Hodgkin disease, with Burkitt lymphoma being associated with the greatest prevalence of kidney invasion (17). Spread to the kidneys is either from contiguous nodes or hematogenous dissemination. Bilateral disease is more common than unilateral.

US usually shows nephromegaly caused by the diffuse infiltrative process. Homogeneous hypoechoic masses are most commonly seen, but, occasionally, the kidneys have increased echogenicity (Fig 10) (18).

• Acute Pyelonephritis

US is routinely used for the workup of patients with urinary tract infections. Although not as sensitive as computed tomography (CT) or DMSA renal scan in detection of acute pyelonephritis, US is an effective screening modality (19). The US findings are variable, and frequently results of the study are normal. Abnormal findings include nephromegaly or focal areas of increased or decreased echogenicity. Occasionally, an underlying cause for infection is found, such as obstruction or renal anomaly. In acute multifocal pyelonephritis, the kidney may be enlarged, and there may be a diffuse increase in parenchymal echogenicity (Fig 11).

Figure 11. Acute pyelonephritis in a 5-year-old boy with Pseudomonas aeruginosa urinary tract infection. (a) Sonogram of the right kidney shows enlargement with diffuse increase in parenchymal echogenicity. The hypoechoic renal pyramids are fairly sharply defined. (b) DMSA renal scintigram obtained with technetium-99m demonstrates multiple defects in the distribution of the radionuclide in the right (R) kidney, a finding consistent with multifocal pyelonephritis. L = left.
Figure 12. Sonogram of an 18-year-old patient with sickle cell hemoglobin SS disease shows diffuse increase in renal cortical echogenicity, which is identical to that in the adjacent liver.

Figure 13. Longitudinal US scan of the right kidney in a 32-month-old boy with oculocerebrorenal syndrome shows diffuse increase in echogenicity.

14a. 14b.

Figures 14, 15. (14) Renal dysplasia in a neonate. (a) Sonogram of the left kidney demonstrates a small, echogenic organ containing small cysts, consistent with a dysplastic kidney. There is no corticomedullary differentiation. (b) Sonogram of the right kidney shows nephromegaly and large noncommunicating cystic spaces consistent with multicystic dysplastic kidney. (15) Sonogram of an 8-year-old girl with chronic renal failure shows a small, echogenic kidney and no recognizable corticomedullary differentiation.
Figure 16. (a) Longitudinal sonogram of a 2-month-old girl with oxalosis shows echogenic renal parenchyma due to nephrocalcinosis. (b) Direct coronal CT scan of the kidneys reveals high attenuation of the renal cortices due to deposition of calcium oxalate in the renal tubules.

- **Sickle Cell Anemia**
  Uroradiologic abnormalities in sickle cell anemia include nephromegaly, calyceal clubbing, and renal papillary necrosis (20). Renal biopsy specimens contain enlarged and congested glomeruli with sickled erythrocytes within the capillary lumen. Findings from electron microscopic study of the glomeruli in such cases are consistent with those seen in cases of membranous or mesangiocapillary glomerulonephritis (21). US has demonstrated both nephromegaly and increased echogenicity in cases of sickle cell anemia (22). The glomerular changes presumably cause the increased parenchymal echogenicity seen in some of these cases (Fig 12).

- **Oculocerebrorenal Syndrome**
  Oculocerebrorenal or Lowe syndrome is an X-linked recessive disorder characterized by severe mental retardation, glaucoma, cataracts, and renal abnormalities. Initially, the renal abnormality is similar to that seen in cases of Fanconi syndrome (proximal renal tubular dysfunction), but progressive deterioration of glomerular function ensues until renal failure occurs (23,24) US images of the kidneys in patients with oculocerebrorenal syndrome may show a diffuse hyperechogenicity (Fig 13).

- **Renal Dysplasia and End-Stage Renal Disease**
  In patients with renal dysplasia or end-stage renal disease of any pathogenesis, the kidneys appear small and highly echogenic on US images (Figs 14, 15).

- **Oxalosis**
  Oxalosis is a rare inborn error of glycine metabolism. Excessive amounts of oxalate are excreted in the urine with subsequent formation of calcium oxalate stones and nephrocalcinosis. Patients commonly present in childhood with nephrolithiasis. There is no effective treatment. Renal failure is progressive (25,26).

  In patients with oxalosis, US demonstrates increased echogenicity of the renal parenchyma (Fig 16).

**SUMMARY**
This article has shown examples of diseases that cause increased renal parenchymal echogenicity in pediatric patients. Although increased echogenicity is a nonspecific finding, its observation is important, since in most instances it signifies the presence of renal disease and alerts radiologists to the need for further investigation.
REFERENCES


