Focal fatty sparing areas of the pediatric steatotic liver: pseudolesions on hepatobiliary phase magnetic resonance images

PURPOSE
Focal fatty sparing in liver can be detected as hyperintense pseudolesions on hepatobiliary phase magnetic resonance imaging (MRI). Distinguishing these pseudolesions from liver lesions may make diagnosis challenging. The aim of this study was to evaluate the imaging features of fatty sparing areas on liver MRI in pediatric patients who have been administered gadoxetate disodium.

METHODS
A total of 63 patients between January 2018 and June 2023 underwent gadoxetate disodium-enhanced liver MRI, and 9 (14%) patients with a focal fatty sparing were included in the study. The fat spared areas were evaluated qualitatively and quantitatively including signal intensity measurements and fat fraction calculations.

RESULTS
The liver MRI examinations of 9 patients (5 boys, 4 girls; aged 8–18 years, median age: 14.4) using gadoxetate disodium were evaluated. Based on in-phase and opposed-phase sequences, 13 areas of focal fatty sparing were identified. The mean fat fraction of the liver and fat spared areas were 26.2% (range, 15-47) and 9% (range, 2-17), respectively. All fat spared areas were hyperintense in the hepatobiliary phase images. The mean relative enhancement ratios of the liver and fat spared areas were 0.78 (range, 0.35-1.6) and 1.11 (range, 0.45-1.9), respectively.

CONCLUSION
Focal fatty sparing in liver in children was observed as hyperintense on hepatobiliary phase MRI, and it should not be identified as a focal liver lesion.

KEYWORDS
Liver, magnetic resonance imaging, gadoxetate disodium, hepatic steatosis, focal fatty sparing, children
Focal fatty infiltration and fatty sparing in liver are well-known phenomenon in adults; however, in children, because of the low incidence of hepatic steatosis, these pseudoleisons may make diagnosis challenging. The purpose of this study was to evaluate signal intensity (SI) features of fat spared areas on liver MRI in pediatric patients who have been administered gadoxetate disodium.

**Methods**

This retrospective study was approved by the Hacettepe University Non-Interventional Clinical Research Ethics Committee; informed patient consent was waived because the study was based on retrospective data analysis (GO 21/1162). The archive of the pediatric radiology unit was retrospectively reviewed for liver MRI examinations performed in our institution between January 2018 and June 2023. A total of 63 patients with indications of focal liver lesion, primary liver tumor, metastasis, and chronic liver disease underwent liver MRI with gadoxetate disodium administration. Patients with chronic parenchymal liver disease were excluded, and 9 patients with fat spared areas were included in the study. The MRI examinations were evaluated by two pediatric radiologists (H.N.O. and G.O.) with 11 and 2 years of experience, respectively, through consensus, using a picture archiving and communication system (PACS; GE Medical Systems, Milwaukee, WI, USA). The following clinical and historical information were evaluated qualitatively and quantitatively. For the quantitative assessment of steatotic liver parenchyma and fat spared areas using the following formula: (hepatobiliary phase SI) – (precontrast SI) / (precontrast SI).

The MRI examinations were performed using 1.5T MRI system (GE Signa HDx Healthcare, Milwaukee, WI, USA) units with an eight-channel phased-array body coil. The imaging protocol of the liver included breath-hold coronal TRUE-FISP (repetition time (TR), 4.3 ms; time to echo (TE), 2.1 ms; flip angle (FA), 60; matrix, 416 × 512; slice thickness, 4.5 mm), axial T2-weighted half-Fourier acquisition single-shot turbo spin-echo (TR, 1350 ms; TE, 92 ms; FA, 160; matrix, 256 × 256; slice thickness, 6 mm), axial in-phase and opposed-phase chemical shift imaging (TR, 160 ms; TE, in-phase: 4.9 ms, opposed-phase: 2.4 ms; FA, 70; matrix, 256 × 192; slice thickness, 6 mm), breath-hold T2-weighted fast spin-echo with fat suppression (TR, 3050 ms; TE, 125 ms; FA, 150; matrix, 256 × 256; slice thickness, 6 mm), and three-dimensional T1-weighted gradient-recalled echo fat-suppressed sequences (TR, 5 ms; TE, 2.4 ms; FA, 10; matrix, 320 × 240; slice thickness, 3 mm) before and after the injection of the contrast agent. A bolus injection of gadoxetate disodium (Primovist, Bayer HealthCare, Berlin, Germany) was administered at a rate of 1 mL/s. The total contrast dose was 0.1 mL/kg of body weight. Diffusion-weighted imaging was used to acquire single-shot echo-planar images (under free-breathing) with b values of 50, 400, and 800 s/mm². The images were acquired in accordance with delayed hepatobiliary phase imaging at 20 min for gadoxetate disodium. Before the MRI examination, an informed consent form was obtained from the patients’ parents regarding the use of gadoxetate disodium. Gadoxetate disodium is a widely used contrast agent in children and has been reported as safe in the literature.

**Results**

Liver MRI examinations of 9 patients (5 boys, 4 girls; aged 8–18 years, median age: 14.4) using gadoxetate disodium were evaluated. The demographic characteristics are summarized in Table 1. None of the patients included in the study had liver cirrhosis.

A total of 13 focal fat spared areas were detected on in-phase and opposed-phase images (Table 2). On the opposed-phase images, the fat spared areas had high SI. The mean fat fraction of the liver and fat spared areas were 26.2% (range, 15–47) and 9% (range, 2–17), respectively. The median delta fat fraction was 15% (range, 12–34). The fat spared areas were hyperintense in 7 (78%) patients and isointense in 2 (22%) patients on fat-suppressed precontrast T1-weighted images (Figure 1). The mean SI of liver and fat spared areas on precontrast fat-suppressed T1-weighted images were 405 (range, 129–891) and 481 (range, 130–1277). The mean SI of liver and fat spared areas on hepatobiliary phase images were 736 (range, 175–1693) and 1112 (range, 203–2834). In the fat-suppressed T2-weighted images, the fat spared areas were hypointense in 5 (55%) patients and isointense in 4 (45%) patients. There was no signal alteration in any of the patients on the diffusion-weighted images. All the detected focal fat spared areas were hyperintense in the hepatobiliary phase images (Figure 1).

### Table 1. Demographic characteristics of the patients

<table>
<thead>
<tr>
<th>Patient no</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Primary diagnoses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13</td>
<td>M</td>
<td>Obesity, geographic liver lesion on abdominal ultrasound</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>F</td>
<td>Hodgkin lymphoma</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>M</td>
<td>Glycogen storage disease</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>F</td>
<td>Diabetes mellitus, PCOS, geographic liver lesion on abdominal ultrasound</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>F</td>
<td>Hypertriglyceridemia, liver lesion on abdominal ultrasound</td>
</tr>
<tr>
<td>6</td>
<td>17</td>
<td>M</td>
<td>Testicular yolk sac tumor</td>
</tr>
<tr>
<td>7</td>
<td>17</td>
<td>M</td>
<td>Hodgkin lymphoma</td>
</tr>
<tr>
<td>8</td>
<td>13</td>
<td>F</td>
<td>Glycogen storage disease</td>
</tr>
<tr>
<td>9</td>
<td>17</td>
<td>M</td>
<td>Hepatic adenoma</td>
</tr>
</tbody>
</table>

**Main points**

- Fatty liver disease has become more common in children in recent years.
- Focal fatty sparing can be detected as mass-like lesions on ultrasonography or computed tomography (CT) and may even show increased fluorodeoxyglucose uptake in positron emission tomography/CT.
- Liver magnetic resonance imaging with hepatobiliary contrast agents can be used as a problem-solving imaging modality in the evaluation of steatotic liver in children.
- Focal fat spared areas in the liver parenchyma may appear as increased signal intensity in the hepatobiliary phase, presumably because of the preserved parenchymal function.
Table 2. Imaging findings of the patients

<table>
<thead>
<tr>
<th>Patient no</th>
<th>Segments of FSAs</th>
<th>T2W fat-suppressed</th>
<th>T1W fat-suppressed</th>
<th>Arterial phase</th>
<th>Portal phase</th>
<th>Delayed phase</th>
<th>Hepatobiliary phase</th>
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<td>1</td>
<td>Segment 7 and 8</td>
<td>Hypointense</td>
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<td>Hyperintense</td>
<td>Hyperintense</td>
<td>Hyperintense</td>
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<tr>
<td>2</td>
<td>Segment 4 and 5</td>
<td>Isointense</td>
<td>Hyperintense</td>
<td>Hyperintense</td>
<td>Hyperintense</td>
<td>Hyperintense</td>
<td>Hyperintense</td>
</tr>
<tr>
<td>3</td>
<td>Segment 2 and 4</td>
<td>Hypointense</td>
<td>Hyperintense</td>
<td>Hyperintense</td>
<td>Hyperintense</td>
<td>Hyperintense</td>
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<tr>
<td>4</td>
<td>Segment 3 and 4</td>
<td>Hypointense</td>
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<tr>
<td>5</td>
<td>Segment 4</td>
<td>Isointense</td>
<td>Hyperintense</td>
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<td>Hyperintense</td>
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<tr>
<td>6</td>
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<tr>
<td>7</td>
<td>Segment 4</td>
<td>Isointense</td>
<td>Isointense</td>
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<tr>
<td>9</td>
<td>Segment 4</td>
<td>Hypointense</td>
<td>Hyperintense</td>
<td>Hyperintense</td>
<td>Hyperintense</td>
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</tr>
</tbody>
</table>

FSAs, fat spared areas.

The mean relative enhancement ratios of the liver and fat spared areas were 0.78 (range, 0.35–1.6) and 1.11 (range, 0.45–1.9), respectively. Fat spared areas were present at segment 1 (n = 1), segment 2 (n = 1), segment 3 (n = 2), segment 4 (n = 7), segment 5 (n = 1), segment 7 (n = 1), and segment 8 (n = 1). Five patients had a fat spared area in more than one liver segment.

Focal nodular hyperplasia was detected in 5 patients, and all of these lesions exhibited gadoxetate disodium retention in the hepatobiliary phase. One patient had histopathologically confirmed inflammatory hepatocellular adenoma that displayed wash-out on hepatobiliary phase images.

**Discussion**

This study produced two major results. First, focal fatty sparing in the pediatric steatotic liver demonstrates increased SI on hepatobiliary phase images. Second, we observed that most of these areas have increased SI on precontrast fat-suppressed T1-weighted images. On in-phase and opposed-phase images, fatty sparing has high SI on the opposed-phase images as a result of the suppressed signal of the other parts of the steatotic liver.

In our study, most of the fat spared areas were in segment 4. Some segments of the liver, such as the gallbladder fossa, medial segment of the left lobe adjacent to the portal vein, and subcapsular areas are more prone to focal fatty sparing. This phenomenon is caused by a third inflow, which is a venous inflow to the liver in addition to the typical dual blood supply (portal vein and hepatic artery). The most common anatomic variations that cause a third inflow are an aberrant right gastric vein, epigastric and paraumbilical veins (Sappey's and Burow's veins), and cholecystic veins. Focal fat spared ar-

![Figure 1](http://example.com/figure1.png)

**Figure 1.** An 18-year-old boy with type 1 glycogen storage disease underwent liver magnetic resonance imaging using a hepatobiliary contrast agent. (a, b) In-phase (a) and opposed-phase (b) images indicating liver steatosis with decreased signal intensity on the opposed-phase image and fat spared areas in segments 2 and 4 (arrows). (c, d) Axial T2-weighted image indicating hypointensity (arrow), and precontrast fat-suppressed T1-weighted image displaying hyperintensity (arrow) at the focal fat spared area. (e) Hyperintensity at the focal fat spared area (arrows) on the hepatobiliary phase image 20 min after gadoxetate disodium injection.
Fatty sparing can be distinguished by the hepatobiliary phase images. In our study, 1 patient had an inflammatory adenoma, which is the most common benign nature of focal fatty sparing. The hyperintensity on hepatobiliary phase images may include secondary to precontrast T1 hyperintensity or hyperfunctional hepatocytes in fatty sparing areas.

In conclusion, liver steatosis may have various imaging manifestations in pediatric patients. Focal fat spared areas in children have been observed as hyperintense on hepatobiliary phase MRI, and they should not be identified as a focal liver lesion.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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