Eur Radiol (2002) 12:2313–2316
DOI 10.1007/s00330-002-1351-0



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# MR imaging of the normal appendix in children

Received: 11 September 2001
Revised: 13 December 2001
Accepted: 18 January 2002
Published online: 9 May 2002


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**Abstract** Our objective was to assess the ability of MR imaging in the detection of the normal appendix, and to describe the MR appearance of the normal appendix. There were 15 healthy volunteers (11 girls, 4 boys; mean age 12.3 years) who underwent MR imaging on a 1.0-T unit. The imaging protocol included axial and coronal T2-weighted ultra turbo spin-echo (UTSE)-weighted images, axial T1-weighted turbo spin-echo (TSE) and coronal short tau inversion recovery (STIR)/TSE sequences. Confidence regarding the detection was scored from 1 (high confidence) to 3 (low confidence). Thickness was measured and MR appearance described. Clinical control after 2 weeks revealed no signs or symptoms of acute appendicitis. The normal appendix was seen in 86% on T2/UTSE-weighted images and in 73% on T1/TSE-weighted images and in none on STIR/TSE images. On axial T2/UTSE-weighted images, normal appendix had a hyperintense center and a hypointense wall, and was mostly hypointense on T1/TSE-weighted images, with a mean thickness of 4.5 mm. Magnetic resonance imaging seems to be an accurate method for the assessment of the normal appendix in children; thus, MR imaging might be an alternative to CT if US examinations are inconclusive.

**Keywords** Pediatrics · Appendix · MR imaging

## Introduction

Acute appendicitis is a common clinical problem and the most frequent reason for laparotomy in children. The rate of unnecessary appendectomies in children up to 18 years of age is 35–45% [1]; thus, children more often undergo radiological preoperative assessment by different imaging modalities to reduce such high negative laparotomy rates [2].

Ultrasound has become an important tool in the diagnosis of acute appendicitis. The development of high-resolution transducers has facilitated the search for the appendix considerably [3, 4, 5, 6]; however, it is often difficult, even for experienced radiologists, to characterize the normal appendix and to rule out acute appendicitis [7, 8, 9, 10]. The retrocecal localization of the appendix, overlying bowel gas, and obese children, as well as the operator-dependent nature of US, are limiting factors [7, 11, 12]. In such patients, CT and MR imaging are recommended as additional imaging tools in the diagnosis of acute appendicitis [13, 14, 15]. The use of CT should be carefully considered due to the risks of ionizing radiation [15, 16, 17, 18, 19, 20]; thus, MR imaging seems to be a favorable tool for the detection of acute appendicitis, particularly in pediatric patients [13, 14].

To date, only signs of acute appendicitis on MR imaging have been described [13, 14]; hence, knowledge of the appearance of the normal appendix on MR imaging seems essential for accurate diagnosis of the inflamed appendix.

The aim of this study was firstly to assess the ability of MR imaging in the detection of the normal appendix, and secondly, to describe the MR appearance of the normal appendix.

## Materials and methods

### Patients

We examined 15 healthy volunteers (11 girls, 4 boys; age range 5–14 years, mean age 12.3 years) randomly included in the study with no history of appendicitis-like symptoms [2]. The inclusion of volunteers did not depend on gender, height, or nutritional condition. Age of volunteers was limited to 17 years to represent a typical pediatric patient population. Written informed consent was obtained from all the children's parents and volunteers depending on their age. To rule out acute appendicitis after the MR examination, all children underwent clinical examination within 2 weeks after the MR examination, and none of them revealed signs or symptoms of acute appendicitis.

### MR imaging

Magnetic resonance imaging of the abdomen with the children in the supine position was performed without sedation or anesthesia using a surface coil, on a 1.0-T MR unit (Philips, Gyroscan, N10-NT, Best, The Netherlands). The examination protocol included T1-weighted turbo spin-echo (T1/TSE; TR/TE: 575 ms/14 ms; 4 acquisitions) in the axial plane, T2-weighted ultra turbo spin-echo (T2/UTSE; TR/TE: 5000 ms/140 ms; 4 acquisitions) in the axial and coronal planes, and fat-suppressed short inversion time inversion recovery turbo spin-echo (STIR/TSE; TR/TI/TE: 1600 ms/139 ms/14 ms; 2 acquisitions) in the axial plane. The slice thickness was 4 mm and the intersection gap 0.4 mm for each sequence. We used a 256×256 matrix, and the field of view varied from 275 to 380 mm, depending on the patient's size.

Examination time for each MR sequence was: 7 min for T1/TSE, 6 min for T2/UTSE, and 9 min for STIR/TSE. The total examination time was 29 min, not including setup time before and after the examination.

### Data analysis

The MR images were reviewed by two MR-experienced radiologists independently. The search for the appendix was focused on the area around the cecum [2, 13] The confidence regarding the detection of the normal appendix was scored for each sequence separately from 1 (high confidence), to 2 (moderate), or to 3 (no confidence). In case of disagreement, the final decision was made by consensus.

Criteria for acute appendicitis with MR imaging have been described in the literature, and none of those signs had to be visible for diagnosing a normal appendix [13, 14]. According to previous published criteria of the normal appendix on CT and US a 6-mm outer diameter was assumed as normal on MR imaging as well [1, 5, 6, 7, 16]. Measurement was performed on every sequence on which the appendix was reliably visible. The appearance of the normal appendix was described for each sequence obtained.

### Statistical analysis

Analysis was performed using a statistical software package (version 6.10; SAS Institute, Cary, N.C.). Results are expressed as the mean. For each sequence obtained, interobserver variability was quantified using the κ coefficient [22].

**Table 1** Grade of confidence and κ-values regarding the detection of the normal appendix for both readers for different MR sequences in 15 healthy volunteers. *TSE* turbo spin echo; *UTSE* ultra turbo spin echo; *STIR* short tau inversion recovery

| MR sequences | Confidence[a] | | | κ-value |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| T1/TSE axial | 11 | 2 | 2 | 0.65 |
| T2/UTSE axial | 13 | 1 | 1 | 0.9 |
| T2/UTSE coronal | 13 | 2 | 0 | 1.0 |
| STIR axial | 0 | 1 | 14 | 1.0 |

[a] *1* high confidence; *2* moderate confidence; *3* no confidence

## Results

Table 1 summarizes the scoring regarding the confidence for detection of the normal appendix for each sequence obtained with a κ coefficient ranging from 0.65 to 1.

With T2/UTSE sequences, the normal appendix was reliably visible in 13 of 15 (86%) children and was superior to T1/TSE images with which the appendix was seen reliably in 11 of 15 (73%) cases. With STIR sequences, the normal appendix was not perceptible with high confidence in any case.

The outer diameter of the 13 visible normal appendices (T1/TSE: 11 cases; T2/UTSE: 13 cases) was less than 6 mm and ranged from 3 to 5 mm, with a mean thickness of 4.5 mm.

On T2/UTSE-weighted images, in all cases the center of the normal appendix was slightly hyperintense and the wall was hypointense (Fig. 1a, b).

A similar appearance was seen in 4 of 11 (36%) cases on T1/TSE-weighted images. In the remaining 7 of 11 (64%) cases, the entire appendix, from the center to the outer wall, was hypointense on T1/TSE-weighted images (Fig. 2).

The detection of the normal appendix with STIR/TSE was only possible with a combination of T1- and T2-weighted images. The normal appendix was visible with moderate confidence in only 1 case (Table 1) on STIR/TSE sequences (Fig. 1c).

## Discussion

Ultrasound has become an established method for depiction of the normal and inflamed appendix, if performed by an experienced examiner [2, 4, 8]. The limiting factors with the use of US include a retrocecal location and obesity, which makes accurate diagnosis more difficult because of the lower spatial resolution of low-frequency transducers. In such patients, and in patients with atypical clinical symptoms, CT and MR imaging have been recommended [15, 23, 24]. Even considering that pa-

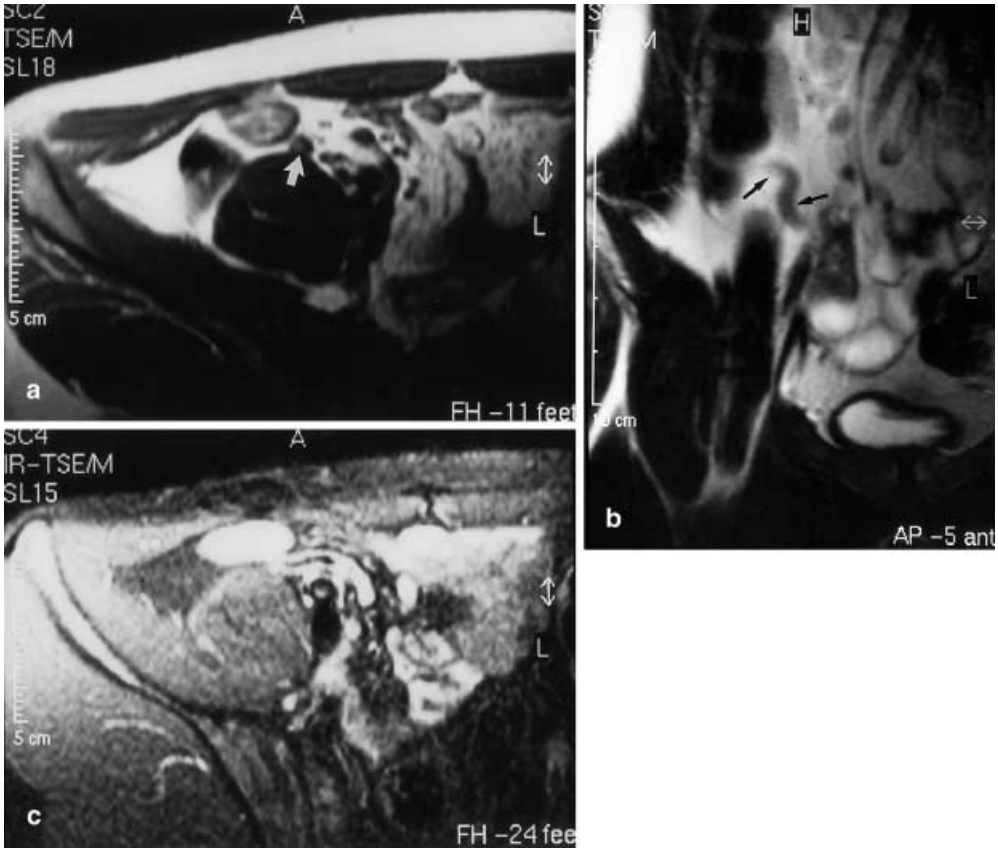


**Fig. 1** **a** Axial and **b** coronal T2-weighted/ultra turbo spin-echo (TR/TE: 5000 ms/140 ms) MR images in a 9-year-old healthy girl. **a** Axial image demonstrates the normal appendix with its hyperintense center and hypointense wall (*arrow*) lying on the psoas muscle. **b** Coronal image demonstrates the hypointense wall and the serpentine course of the normal appendix (*arrows*). **c** Axial short tau inversion recovery/turbo spin-echo (TSE; TR/TI/TE:1600 ms/139 ms/14 ms) illustrating the poor resolution of the sequence for anatomical details of the normal appendix

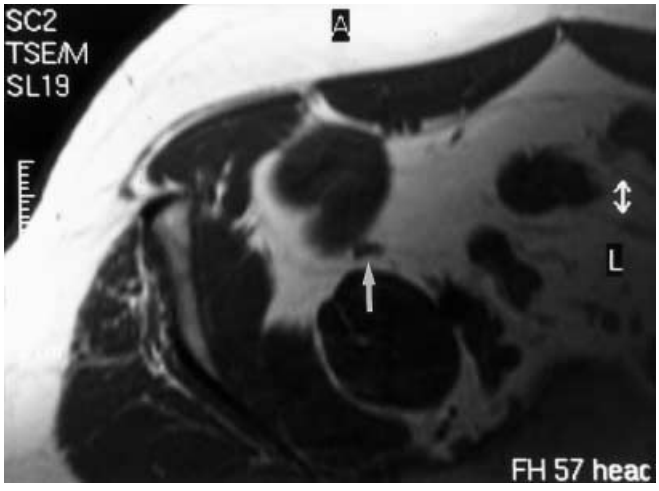


**Fig. 2** Axial T1/TSE (TR/TE: 575 ms/14 ms) MR image in a 12-year-old healthy boy demonstrates the normal appendix (*arrow*) with its hypointense wall surrounded by mesenteric fat

tients who present with symptoms of acute appendicitis would include a generally young and female patient population with gynecological disorders that could mimic acute appendicitis, MR imaging seems to be a favorable choice of an additional assessment modality [2, 13, 24]. Magnetic resonance imaging unites the benefits of an operator-independent, non-ionizing imaging technique without the use of contrast media application; thus, in such a selective patient population, higher cost and lack of availability of MR imaging should not be seen as a limitation. To date, only signs of acute appendicitis on MR imaging have been described [13, 14]; hence, knowledge of the appearance of the normal appendix on MR imaging seems essential for accurate diagnosis of the inflamed appendix.

Our results demonstrate that MR imaging allows accurate depiction of the normal appendix. On MR imaging, the normal appendix was visible in 13 of 15 (86%) of the volunteers; thus, MR imaging seems to be superior to other imaging modalities that report visibility rates of up to 80% (US) and up to 51% (CT) [5, 24].

In addition, MR imaging has an almost excellent interobserver agreement ($\kappa$=0.65–1) in the detection of the normal and inflamed appendix as reported previously [13].

The key for to a diagnostically adequate MR examination is the choice of proper MR sequences. As shown in our study, T2/UTSE-weighted images are ideally suited for visualizing the normal appendix, whereas STIR/TSE sequences failed, because of the poor resolution for anatomical details. On the other hand, STIR/TSE

sequences are the most sensitive sequences for free-fluid collections and inflammatory changes of fatty tissue and are used routinely for detection of the inflamed appendix [13]; thus, an approach that combines these two sequences is necessary. The use of T1/TSE-weighted images does not seem necessary for the depiction of the normal appendix nor for the inflamed appendix as shown previously [13, 14].

On US, a normal appendix is defined by a three-ring appearance (mucosa, submucosa, and muscularis propria) with a diameter of less than 6 mm [5, 7, 11]. In accordance with these results, the diameter of the normal appendix ranged from 3 to 5 mm on MR imaging. The typical US appearance of three rings was not seen on MR imaging. On T2/UTSE-weighted sequences, the center was hyperintense and the wall hypointense. In most cases (10 of 15), the entire wall of the normal appendix was hypointense on T1/TSE-weighted images. The hyperintense center of the appendix was interpreted as the liquid content of the mucosa. Differentiation between the submucosa and muscularis propria, as described with US, was not possible on MR imaging [5].

In two asthenic volunteers, the normal appendix could not been seen on MR imaging, which might be explained by the lack of mesenteric fat. In contrast, the normal appendix was seen easily with US in these volunteers. This advantage of US is not surprising, because in asthenic patients US facilitates the depiction of the appendix more easily, as described previously [25].

In conclusion, MR imaging seems to be an accurate method for the assessment of the normal appendix [13, 14]; thus, MR imaging should be considered as alternative for CT if US examinations are inconclusive. Further studies are necessary to emphasize the importance of MR imaging in the diagnosis and exclusion of acute appendicitis.

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