Ultrasonographic features of children presenting with abdominal pain : normal versus abnormal

Wiersma, F.

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Ultrasonographic features of the normal appendix and surrounding area in children.

Fraukje Wiersma
Alexandr Šrámek
Herma C. Holscher

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Abstract

Introduction:
The purpose of this study is to evaluate prospectively the frequency of depiction with ultrasonography (US) of the appendix in children without a clinical suspicion of acute appendicitis and to evaluate the US appearance of the normal appendix.

Materials and Methods:
Between March 2003 and July 2003, 146 consecutive patients (62 boys and 84 girls; mean age, 7 years; age range, 2-15 years) without clinical suspicion of acute appendicitis were examined with US. Patients with cystic fibrosis and those with acute abdominal pain were excluded from the study. Outer diameters, mural thickness, and color Doppler flow were measured. Appendiceal lumen and surroundings of the appendix were determined. The overall diameter and mural thickness of the appendix were examined for relationship to age, weight, or height of the patient. For the statistical analysis, the Mann-Whitney test, Student *t* test, and linear regression analysis were applied.

Results:
In 120 (82%) children, the appendix was depicted with US; in 26 (18%) children, this was not possible. In 114 (95%) of the depicted appendices, the position was classical; we observed six (5%) retrocecal appendices. All appendices were compressible. Mean diameter of the appendix was 0.39 cm (range, 0.21-0.64 cm) and the mean mural thickness was 0.18 cm (range, 0.11-0.27 cm). The appendiceal lumen was empty in 74 (62%) children. The others were filled with fecal material, gas, or both. In 75 (51%) of the 146 children, lymph nodes were present in the right lower quadrant of the abdomen. We found no relation between the age, weight, or height of the examined child and the overall diameter or wall of the appendix.

Conclusion:
The results of this study show that a normal appendix can be depicted with US in 82% of asymptomatic children.

Introduction

In 1986, graded-compression ultrasonography (US) was reported to have been used in the diagnosis of acute appendicitis in children and adults [1]. Because of technical limitations of the US machines used in those days, the only criterion for acute appendicitis was mere depiction of the appendix with US. A normal appendix that was not inflamed, however, would not be depicted. US machines in general and resolution in particular have improved dramatically since then; now, both inflamed and normal appendices can be depicted with US.

To discriminate an inflamed from a normal appendix, several additional criteria for appendicitis were established, such as the outer diameter of the appendix, compressibility of the appendix, shape of the appendix, and absence of gas in the appendiceal lumen [2-4]. These criteria have been investigated in the adult population. Less is known, however, about the US appearance of the normal appendix in the pediatric population without clinical suspicion of acute appendicitis. Thus, the purpose of our study was to evaluate prospectively the frequency of depiction with US of the appendix in children without clinical suspicion of acute appendicitis and to evaluate the US appearance of the normal appendix.

Materials and Methods

Patients

From March 2003 to July 2003, consecutive patients aged 2-15 years referred to the department of radiology of the Juliana Children's Hospital to undergo US were included in our study. The majority of the patients were referred for examination of the urinary tract or because of chronic abdominal pain. Patients who were referred because of acute abdominal pain were excluded from the study. Children with cystic fibrosis were also excluded from this study because in a recent study, an enlarged appendix was found in children with cystic fibrosis but without clinical signs of acute appendicitis [5]. Patients younger than 2 years were excluded because of difficulty in performing the examination; these patients are very active, and sometimes they are reluctant to undergo an extensive examination. Furthermore, the incidence of acute appendicitis in such a young age group is low. Patients who had undergone previous appendectomy were also excluded. From a total of 482 abdominal US examinations performed at our department, 146 patients with a mean age of 7 years (age range, 2-15 years) were included in our investigation. The mean age for girls was 7.3 years (age range, 2-14 years), and the mean age for boys was 6.5 years (age range, 2-15 years). Additional US evaluation of the right lower quadrant of the abdomen was performed. The patient population consisted of 62 boys and 84 girls. Informed consent was obtained from each patient and/or his or her parents, as per the rules of our country. Institutional review board approval was obtained for our study. For each patient, the weight (measured in kilograms) and height (measured in meters) were recorded in order to calculate the body mass index (BMI).

Measurements

Transverse and longitudinal images of the appendix were obtained by using an HDI 5000 scanner (ATL HDI 5000, Philips Medical Systems) with a 7-12 MHz linear-array transducer. The US examinations were performed by a pediatric radiologist (H.C.H.) or an experienced resident of radiology. The radiologist has 12 years of experience in pediatric abdominal US. The three residents were in the third year of their education, and they each had about 6 months of specific experience.

The maximum time to depict the appendix was set at 15 minutes. If 15 minutes were not enough, the examination was concluded, and the appendix was considered unable to be depicted on the basis of our prior experience. We labeled a structure as a normal appendix when it appeared as a blind-ending lamellated structure without peristalsis (Figure 1). The depiction of the appendix was subdivided into partial or complete (including the tip of the appendix). The position of the appendix was determined (i.e., classical or retrocecal). The classical position above the iliac vessels pointing in the direction of the bladder and the position of the appendix above the colon in the paracolic gutter were both set as classical (Figure 2). Subsequently, the overall diameter with and without compression was measured. For measurement of the diameter with compression, we used the graded compression technique described by Puylaert [1]. To measure diameters, the electronic calipers were placed between the outer borders of the hypoechoic tunica muscularis. The outer diameters were measured in the transverse plane of the appendix. The mural thickness of the appendix was defined as the distance from the hyperechoic luminal interface to the outer hyperechoic line. Subsequently, the content of the appendiceal lumen was determined. The content was classified either as empty or as filled with gas, fecal material, or both (Figure 3). Furthermore, the blood flow in the appendiceal wall was determined by color Doppler US. The criteria for blood flow were classified as follows: no detectable flow, a single vessel within the appendiceal wall, and multiple vessels in the appendiceal wall. Finally, we examined the area surrounding the appendix for the presence of fluid, inflamed fat and/or mesenteric lymph nodes. We labeled tissue as inflamed fat when it was recognized with US as hyperechoic, non-compressible intraabdominal fatty tissue around the appendix [6]. All the measurements and findings were noted immediately after imaging.

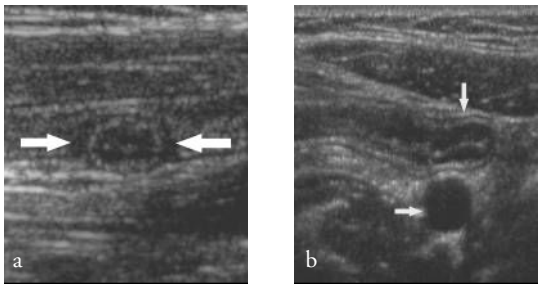

Figure 1.

US image of the normal appendix. (a) Round transverse section of the proximal part of a normal appendix (arrows). (b) Longitudinal section of a normal appendix (vertical arrow) in the classical position above the iliac artery (horizontal arrow).

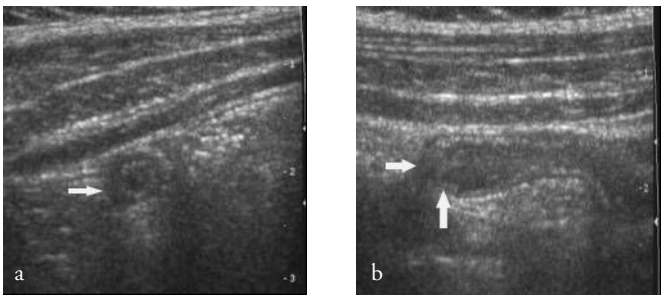

Figure 2.

US images of the normal appendix show (a) transverse and (b) longitudinal section of the appendix in the paracolic gutter (arrows).

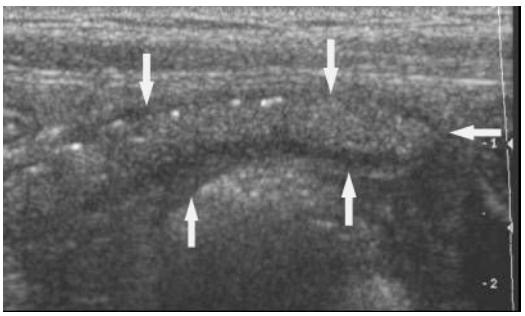

Figure 3.

US image shows the longitudinal section of a normal appendix. The appendiceal cavity is filled with gas and fecal material (arrows).

Statistical Analysis

The distributions of the continuous variables were tested for normality by using the Kolmogorov-Smirnov test. The upper limit of the normal range of the continuous variables was set at the mean plus two times the standard deviation or the 95th percentile for variables that were not normally distributed. The results that concern discrete variables were expressed as frequencies. For the comparison of subgroups, the Student *t* test or the Mann-Whitney test for nonnormally distributed subgroups was used. Linear regression analysis was performed by analyzing one variable at a time and was used to examine whether the overall diameter or the thickness of the appendiceal wall is related to age, weight, or height of the examined child. The regression coefficient of the continuous variable indicates the increase or decrease of the diameter or mural thickness of the appendix for every unit increase in the studied continuous variables (e.g., age and weight). A p value of less then 0.05 was considered to indicate a statistically significant difference (F.W., A.Š.).

Results

General Characteristics

The general characteristics of the study population are shown in Table 1. Of the 482 patients referred to our department for abdominal US, 146 were included in our study. Reasons for exclusions were cystic fibrosis (n = 3), age younger than 2 years (n = 141) and acute abdominal pain or a medical history of appendectomy (n = 192). The mean age for boys and girls were 6.50 and 7.30 years, respectively. There was no significant difference in age between boys and girls (p = 0.1). The mean BMI of the study population was 17. The children in whom the appendix was not depicted (BMI of 19) did not have a significantly higher mean BMI than those in whom the appendix was depicted (BMI of 17) (Mann-Whitney test; p = 0.4).

Table 1 Patient Characteristics

Characteristics	Data
Sex	
Girl	84
Boy	62
Age (y)*	7 ± 3.3
Weight (kg)*	28.5 ± 13.2
Length (m)*	1.3 ± 0.2
BMI*	17 ± 3.9
Indication	
Urinary tract problems	66
Chronic abdominal pain	63
Other reasons [a]	17

Note.—Unless otherwise indicated, data are number of patients.

* Data are mean ± standard deviation

[a] The other reasons consisted of gynecologic disorders, liver disorders, gastric carcinoma, inguinal hernia, umbilical hernia, coccygeal pain, rupture of the spleen and chronic vomiting.

Appendiceal Appearance

In 118 (81%) patients, the appendix was depicted completely (Table 2), whereas in 26 (18%) patients, it was not depicted at all. Of the 26 patients in whom the appendix could not be depicted, eight (31%) had urinary tract problems, 14 (54%) had chronic abdominal pain, and four (15%) had other indications. In two (1%) patients, the appendix was only partial visible. There was a difference in depiction between children with urinary tract problems and chronic abdominal pain (difference, 10%; 95% confidence interval: –3%, 23%). In children with chronic abdominal pain, the appendix was depicted less frequently than in children with urinary tract problems. Results of the measurements of the anteroposterior, left-to-right diameter, and appendiceal mural thickness are summarized in Table 2. The position of the appendix was classical in 114 (95%) patients and retrocecal in six (5%). All of the depicted appendices were compressible (Table 3). The appendiceal lumen was empty in 74 (62%) of the patients. In 14 (12%) of the patients, the appendix was filled with gas, and in 29 (24%), the appendix was filled with fecal material. Two appendices were filled with gas and fecal material. Two appendices exhibited a sparse flow. None of the depicted appendices contained an appendicolith.

Table 2 Appendiceal diameter and mural thickness

Diameter and thickness	Range (cm)	Mean (cm)	Standard deviation (cm)	Two standard deviations (cm)
Diameter				
Anteroposterior	0.21-0.64	0.39	0.08	0.55
Left to right	0.28-0.85	0.56	0.11	0.78
Anteroposterior with compression*	0.16-0.64	0.38	0.09	0.56
Left to right with compression	0.24-0.85	0.57	0.11	0.79
Mural thickness*	0.11-0.27	0.18		0.30[a]

Note.—Results are in the 120 children with depicted appendix out of 146 studied.

* Nonnormal distribution.

[a] 95% confidence interval: 0.17, 0.19

Table 3 Appendiceal appearance and environment

Appearance and environment		Frequency	Percentage
Compressibility	Yes	120	100
	No	0	0
Lumen content	Empty	74	62
	Gas	14	12
	Fecal material	29	24
	Gas and fecal material	3	2
Color Doppler flow	None or normal	118	98
	Increased	2	2
Surrounding area*	No fat, fluid, or lymph nodes	68	47
	Inflamed fat	3	2
	Lymph nodes	75	51
Lymph nodes (<1 cm)*	None	71	49
	<5	40	27
	>5	35	24

Note.—Results are in the 120 children with depicted appendix out of 146 studied.

* Results are in the 146 children studied.

Surrounding environment

In three patients, we detected inflamed fat in the right lower quadrant of the abdomen. One of these patients later proved to have Crohn disease and had a terminal ileitis (Figure 4). In the remaining two patients, the appearance of fat had returned to normal by the time follow-up examinations were performed. The cause of the inflamed fat cannot be clarified. This might possibly be due to a local self-limiting infection.

In 75 (51%) of the 146 patients, lymph nodes were present in the right lower quadrant of the abdomen (Figure 5). In 35 (24%) of the patients, we observed more than five nodes. There was no significant difference (p = 0.1) in presence of lymph nodes between children who were referred for urologic problems and children with chronic abdominal problems.

Regression analysis showed no evidence of a relationship between age, weight, and height of the examined child and the diameter or mural thickness of the appendix. Although there may be a relationship between these variables, the present study with 120 patients had 90% power to depict correlations of more than 0.3. Results of this analysis are shown in Table 4.

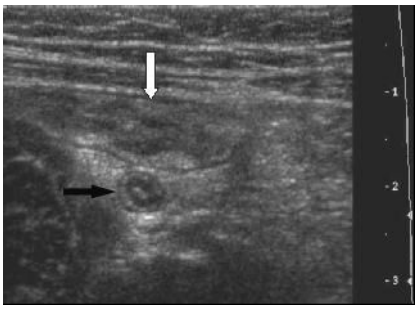

Figure 4.

US image shows the transverse section of a normal appendix (black arrow) surrounded with inflamed fat. Note the thickened wall of the terminal ileum (white arrow).

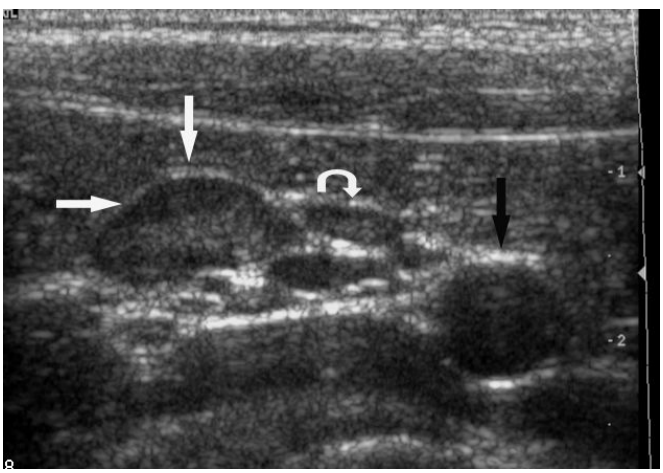

Figure 5.

US image shows mesenteric lymph nodes in the right lower quadrant of the abdomen. A lymph node (anteroposterior; diameter, 5 mm) (straight arrows) with a slightly echogenic center is noted lateral to the iliac artery (black arrow). A very small lymph node is noted next to this node (curved arrow).

Table 4 Regression analysis

		Diameter (AP)[a] (cm)	Diameter (LR)[b] (cm)	Mural thickness (cm)
Age				
	Regression coefficient	0.02	$-4.5^{-0.5}$	0.02
	95% Confidence Interval	-0.03, 0.07	-0.01, 0.01	0.00, 0.04
Weight				
	Regression coefficient	-0.004	-0.004	0.003
	95% Confidence Interval	-0.002, 0.001	-0.003, 0,002	0.000, 0.001
Height				
	Regression coefficient	0.22	0.26	0.25
	95% Confidence Interval	-0.06, 0,11	-0.08, 0.14	-0.01, 0.6

Note.—Results are in the 120 children with depicted appendix out of 146 studied.

[a] AP=anteroposterior, [b] LR=left-right.

Discussion

In this study, we analyzed how frequently the normal appendix could be depicted in children. We found that 82% of appendices were depicted. Šimonovský [7] found that 49% of appendices were depicted in a group of patients in whom clinical appendicitis was not suspected. In our study, we analyzed only pediatric patients (age range, 2-15 years), while Šimonovský included patients from all age groups (age range, 1-84 years). In a later study, Šimonovský [8] found that 58% of appendices were depicted in asymptomatic patients (age range, 1-82 years).

The difference in size between the diameter with and without compression was small. Our explanation for this finding was that an appendix is usually depicted only when compression is applied during the US examination. With maximal pressure, most appendices could be compressed more.

To our knowledge, only Šimonovský [8] had investigated one characteristic of the appendix in a pediatric population. He analyzed the difference in mean appendiceal mural thickness between children and adults. He found a significant difference in mural thickness between infants (1-6 years of age) and adolescents and adults (16-82 years of age); mural thickness was 0.19 cm in infants and 0.21 cm in adults. In our investigation, we found a mean mural thickness of 0.18 cm. Moreover, we found no relation between the age of the examined child and the mural thickness of the appendix. An explanation for this finding might be the presence of some lymphoid hyperplasia of the appendix in children, independent of age.

Only 13.5% of the depicted appendices contained intraluminal gas. Rettenbacher et al. [2] showed that presence of gas in the appendix is useful in the exclusion of appendicitis, while the absence of gas helps in proving appendicitis. Our results are supported by the results of Rao et al. [9]. They conclude that intraluminal gas is not a diagnostic finding in patients who undergo imaging for clinical suspicion of appendicitis. Air is seen in both inflamed appendices and normal

appendices. Intraluminal air cannot be presumed to indicate that the appendix is normal [9].

We were able to depict the appendix with US in 120 (82%) of 146 patients. In 26 (18%) patients, the appendix was not depicted. An explanation could be the size of the patient. In several studies, obesity is given as a major reason for not depicting the appendix [4, 10]. We too assumed that the appendix was more difficult to depict in obese children than in patients with a normal BMI; however, we found no significant difference in BMI between children in whom the appendix was not depicted and children in whom the appendix was depicted. Our subjects are thinner than average American children. Obesity is a bigger problem in the United States than it is in Europe [11, 12].

Another explanation for not depicting the appendix with US is the position of the appendix. Puig et al. [10] suggested that a retrocecal position of the appendix could be an explanation. In a report by Rettenbacher et al. [4], the retrocecal position is a reason for not depicting the appendix. Ceres et al. [13] found that 28% of the examined children had a retrocecal appendix. In our study, only six (5%) children had a retrocecal appendix. A retrocecal appendix might be a reason for failure to depict the appendix in our investigation.

In eight (12%) of the 66 patients with urinary tract problems and 14 (22%) of the 63 patients with chronic abdominal pain (difference, 10%; 95% confidence interval: –3%, 23%), the appendix could not be observed. This difference in depiction might be due to the fact that in populations with chronic abdominal pain, constipation is a more frequent symptom. Depiction of the appendix is made more difficult by intestines filled with fecal material and air.

A prominent finding in our study was the high percentage of children in which mesenteric lymph nodes smaller than 1 cm were observed in the right lower quadrant of the abdomen. In almost 53% of the patients, we found lymph nodes in this region of the abdomen. In nearly 25% of these patients, we observed more then five lymph nodes. Because there was no difference between children with urinary tract problems and children with chronic abdominal complaints, we may assume that the presence of lymph nodes at US in the abdomen of a child is a nonspecific finding with no clinical importance. In the current literature, little is known about this.

There are some limitations in this study. First, there was a lack of comparison with pediatric patients in whom appendicitis was clinically suspected. We indeed had no pathologic proof that the examined patients actually had a normal appendix. Another limitation was the potential operator experience because of the three residents.

The results of this study show that in 82% of the children without clinical suspicion of appendicitis, the normal appendix can be depicted with US. A mean diameter of 0.39 cm and 0.38 cm with compression and a mural thickness of 0.18 cm might be considered normal in this population. The lumen of the appendices in most of the children was empty, and in more than half of the children lymph nodes were present at US. We did not find any relationship between the overall diameter or mural thickness and the age, weight, or length of the examined child. Furthermore, our results indicate that the presence of mesenterial lymph nodes smaller than 1 cm in the abdomen of a child is a nonspecific finding.

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