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ORIGINAL ARTICLE

Rate of and factors affecting sonographic visualization of the appendix in asymptomatic children

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Abstract Reported sonographic visualization rates of the appendix in children are variable. Visualization rates may be affected by patient's age and various patients' physical characteristics. The purpose of this study is to determine the frequency of sonographic visualization of the appendix by pediatric sonographers, to assess factors that may affect visualization of the appendix, and to define the characteristics of the appendix and periappendiceal region in asymptomatic children. Asymptomatic children between the ages of 2 and 18 were prospectively enrolled and evaluated for 15 min by pediatric sonographers. Of the 123 patients, the entire appendix was seen in 68 patients (55.2 %) and at least partially visualized in an additional 14 for a total of 82 patients (66.7 %). Visualization rate was not affected by body mass index, age, or gender. Appendiceal characteristics and periappendiceal findings were similar to previously published data. The average time required to initially detect the appendix was 275.2+211.3 s.

Keywords Pediatric appendix · Ultrasound · Normal characteristics

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Introduction

Imaging plays an integral role in the evaluation of abdominal pain. In children, ultrasound is often employed as the initial imaging modality because of its lack of ionizing radiation [1]. In the evaluation of possible appendicitis, ultrasound offers high sensitivity and specificity [2, 3]. While nonvisualization of the appendix has a high negative predictive value for appendicitis, visualization of a normal appendix virtually excludes the diagnosis. Visualization rates of the normal appendix reported in the literature vary widely; in pediatric patients, studies suggest that the appendix should be visible in its entirety in 82 % of pediatric patients [4] and, even more frequently, in younger pediatric patients [5]. The purpose of this study is to determine the frequency of sonographic visualization of the normal appendix by pediatric sonographers, to assess factors that may affect visualization of the appendix, and to define the characteristics of the appendix in asymptomatic children.

Methods

This study was approved by the institutional review board. Children between the ages of 2 and 18 were prospectively enrolled after obtaining informed consent. Enrollment was voluntary with the study group derived from patients presenting to our department for nonacute outpatient ultrasound imaging. Patients with abdominal/pelvic pain, known disease affecting bowel, and prior appendectomy were excluded. All patients were imaged on GE LOGIQ E9 units utilizing 6–16-MHz linear transducers and an "appendix" preset using tissue harmonic imaging to reduce artifacts and improve imaging of the bowel; frequency and focal zone were optimized for each patient. All patients underwent a systematic examination of the right lower quadrant with graded compression; the cecum,

terminal ileum, and iliac vessels were identified [5]. Each examination was carried out for 15 min which was the time-frame utilized by previous authors [3]. If the appendix was identified, diameter, mural thickness and vascularity, and luminal content were evaluated. If the appendix was not seen, the pelvis and retrocecal locations were examined [5]. All examinations were performed by pediatric sonographers (seven different sonographers with an average of greater than a 10-year experience) and reviewed by a pediatric radiologist. Periappendiceal findings (presence of free fluid and mesenteric adenopathy) and biometric data (age, height, weight, and gender) were tabulated for all patients.

Results

A total of 125 patients were enrolled; two patients were scanned but subsequently excluded (one patient withdrew, and one patient was unsure of prior surgical history). Most commonly, enrollees in this study presented for renal/retroperitoneal (59.3 %), followed by abdominal survey (13.8 %), single-organ abdominal (13.0 %), neck (6.5 %), extremity (3.3 %), pelvis (3.3 %), and scrotal (1.6 %) ultrasound examinations. Of the 123 patients, 86 were female, and 37 were male. The entire appendix was seen in 68 patients (55.2 %) and at least partially visualized in an additional 14 for a total of 82 patients (66.7 %) (Fig. 1).

Patients were divided into two groups: "appendix visualized" (group 1) and "appendix not visualized" (group 2), to determine if age, gender, or body mass index (BMI) influenced visualization of the appendix. The average age of group 1 was 10.3±4.5 years (mean±SD), compared to the average age of group 2 which was 8.6±4.7 years (p=0.07, t test). The average BMI of group 1 was 19.4±4.7, compared to group 2 which was 18.2±4.3 (p=0.18, t test). The appendix was visualized in 56/86 (65.1 %) females and 26/37 (70.2 %) males (p=0.36, chi-squared test).

Appendiceal characteristics, including diameter, mural thickness, luminal contents, and vascularity, and presence of right lower quadrant fluid and mesenteric adenopathy were evaluated. The average diameter of the appendix was 4.2±1.1 mm. The average mural thickness was 1.2±0.5 mm. The lumen was empty in 50 (61.0 %), contained air or enteric contents in 26 (31.7 %) and fluid in six (7.1 %). Color Doppler flow was demonstrated in the appendix in 46 (56.1 %); flow was minimal in 22 (26.8 %) and moderate in 24 (29.3 %) of the 82 visualized appendixes (p=0.00001, binomial test comparing to published data of Wiersma et al. [4] and Hahn et al. [6]). Anechoic right lower quadrant fluid was present in 23 of 123 (18.7 %); right lower quadrant fluid was noted in 15 of 86 females (17.4 %) and 8 of 37 males (21.6 %) (p=0.55, chi-squared test). At least one mesenteric lymph node was found in 72 of 123 (58.5 %).

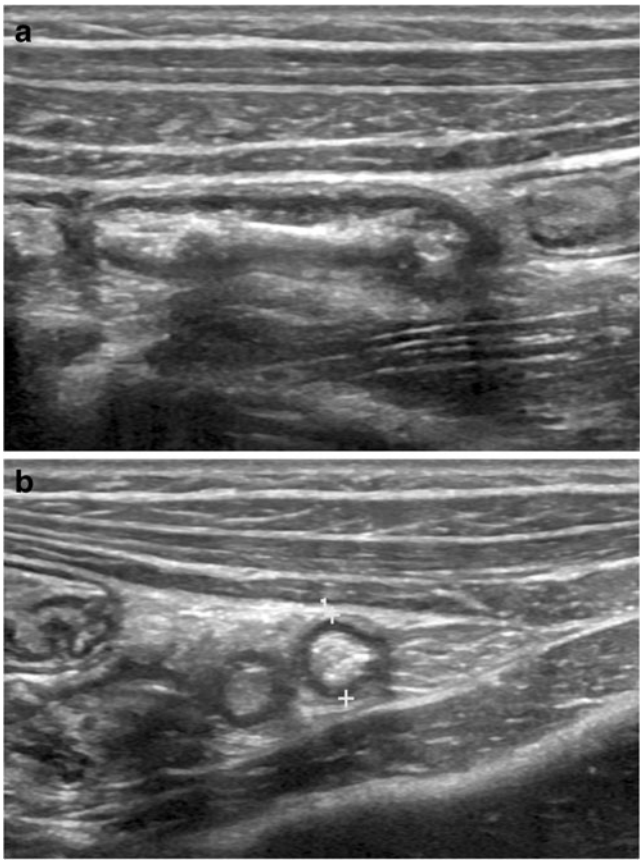

Fig. 1 Longitudinal (**a**) and transverse (**b**) images of a normal appendix

The average time required to initially detect the appendix was 275.2±211.3 s (range 18–865, median 220 s). During the first half of the study, the average time to visualize the appendix was 271.2.2±204.6 s, compared to the second half of 281.9±240.9 s (p=0.82, t test). In the first half of the study, the appendix was seen in 22 of 41, compared to 29 of 41 in the second half (p=0.12, chi-squared test).

Discussion

Sonographic visualization of the appendix in children may be impacted by patient and technical factors. Generally, children are smaller than adults and have less abdominal fat, which allow a smaller field of view and optimal imaging, but patient cooperation and other reasons may limit pediatric examinations. Certain body types, excessive bowel gas, and retrocecal and deep pelvic locations may preclude appendix visualization [4, 7–9]. The skill and experience of the sonologist performing appendix ultrasound examinations vary; further, the sonologist may be a physician, resident, technologist, or some combination thereof. The variable performance of different ultrasound units and platforms also needs to be taken into account. Our study is standardized to experienced

Table 1 Summary of recent normal pediatric appendix studies

	Current study *N*=123	Wiersma et al. [4] *N*=146	Ozel et al. [10] *N*=205	Hahn et al. [5] *N*=274
Appendix visualization rate	66.7 %	82 %	69.3 %	74 % (86 %<9 years old)
Appendix diameter (mm)	4.2±1.1	3.9±0.08	4.2±0.9	4.1
Mural thickness (mm)	1.2±0.5	1.8±0.06		
Color Doppler flow (%)	56.1	2		<1
Empty lumen (%)	61.0	62		
Luminal gas/feces (%)	31.7	38		
Luminal fluid (%)	7.1	0		
RLQ fluid (%)	18.7	0		
Mesenteric nodes (%)	58.5	51		
Time to appendix visualization (average; min)	4.6			3.7
Primary conclusion	Appendix visualization not related to age, gender, or BMI	Appendiceal diameter and mural thickness are not related to age or BMI	Appendix visualization indirectly related to age and BMI	Appendix visualization rate suitable to exclude appendicitis

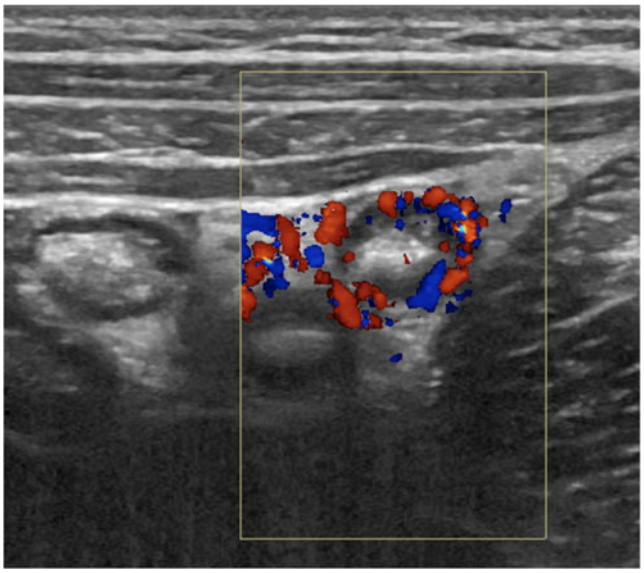

Fig. 2 Color Doppler transverse image of the appendix in a 7-year-old female presenting for renal ultrasound evaluation of enuresis

pediatric technologists who performed examinations using common vendor/platform state-of-the-art ultrasound units.

Many studies [4, 5, 10] have evaluated appendix visualization and characteristics in asymptomatic children (Table 1). While nonvisualization of the appendix with absent secondary signs of appendicitis offers a very high negative predictive value [3, 11], visualization of a normal appendix in its entirety allows confident exclusion of appendicitis [4]. Visualization rates of the normal appendix reported in the literature range between 22 and 98 %, with several pediatric

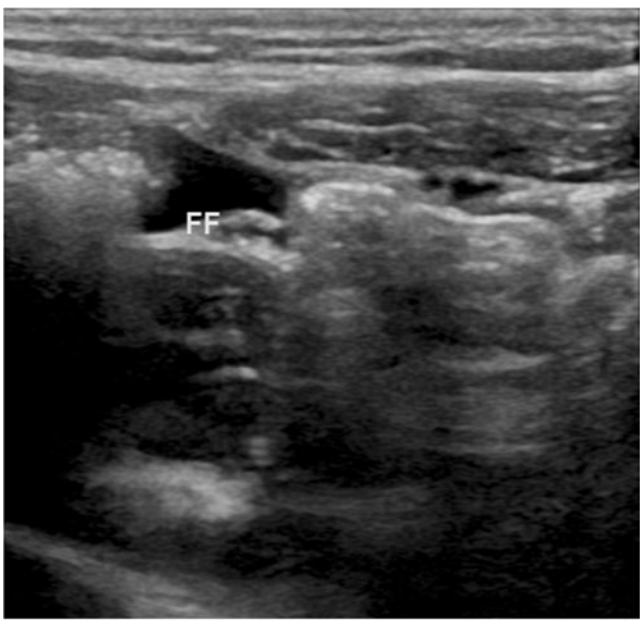

Fig. 3 Image of the right lower quadrant in an 11-year-old male presenting for renal ultrasound evaluation of hypertension

specific studies reporting rates in the upper end of this range [12, 13]. The preponderance of girls in our study likely reflects the higher number of renal/retroperitoneal ultrasounds which were largely performed for assessment of renal growth in patients with vesicoureteral reflux. Patients in the nonvisualization of the appendix group (group 2) tended to be younger than those in the visualization group (group 1), but the difference was not statistically significant. Body mass index was not statistically different between the nonvisualization (group 2) and visualization (group 1) patients and, in fact, was normal in both. As such, nonvisualization of the appendix could not be attributed to a large body habitus. Therefore, BMI, age, and gender were not factors for us in those patients whom we could not visualize the appendix. Ultrasound is an expeditious means to evaluate for appendicitis. The average time to appendix visualization was 4.6 min, which compares favorably with the time required to perform a CT scan. The longest time to visualization was 14.4 min. It can be inferred that, if the appendix is detectable by ultrasound, 15 min should be an adequate length of time to devote to this type of examination. The observations that the appendix visualization rate and the average time to visualization were not significantly different, comparing the first half of the study to the second half, probably relate to the experience level of the sonographers.

More than half of appendixes in asymptomatic patients demonstrated color Doppler flow, and slightly more than half of these were moderately hyperemic (Fig. 2). In the proper clinical setting, color Doppler has been used to support the ultrasound diagnosis of acute appendicitis [14–16]. Color Doppler in acute appendicitis may demonstrate hyperemia, and in gangrenous appendicitis, flow may be absent. Determination of color Doppler flow in our study was subjectively graded as none, minimal, and moderate; the subjective assessment limits the validity of this observation. Baldissertto and Peletti [14] found that the difference between color Doppler flows of normal and inflamed appendices was not significantly enough to be used as a sole discriminator; this has been our experience as well.

Right lower quadrant free fluid was seen in nearly one in five asymptomatic patients (Fig. 3). This is similar to Kessler et al. [15] where free peritoneal fluid was seen in almost 30 % of symptomatic patients with negative ultrasound examinations; Simanovsky et al. [17] found less than 1 ml of fluid in 6 % of asymptomatic boys and girls less than 15 years of age. Interestingly, free fluid was found as often in asymptomatic males as females. The variability of the presence of right lower quadrant free fluid suggests that care should be used with this parameter to discriminate pathology.

Conclusions

In asymptomatic children, the appendix is visualized in its entirety in 55.2 % and at least partially in 66.7 % by experienced pediatric sonographers during a 15-min examination. Visualization is not related to gender, age, or BMI.

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