Criteria for distinguishing the appendix from ileal segments sonographically: a different perspective

Apendiksin ileal segmentlerden sonografik olarak ayırtedilebilmesi için gerekli kriterler: farklı bir bakış açısı

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Abstract

Aim: We aimed to establish the new and objective criteria that can be used for distinguishing the normal or pathological appendix from ileal segments sonographically.

Materials and Methods: Long diameter, short diameter, mean diameter, circularity index (CI), and diameter index (DI) in mm on transverse images of normal and pathological appendices, and the others form of the ileum, were calculated.

Results: DI, CI, long dimension show high sensitivity and specificity in discrimination of the normal or pathological appendix from ileal segments.

Conclusion: DI, CI, and long dimension are effective and objective criteria for distinguishing normal or pathological appendix from ileum sonographically.

Key words: Appendix, appendicitis, ileum, ultrasound imaging, diagnosis

Öz

Amaç: Biz bu çalışmada normal veya patolojik apendiksin ileal segmentlerden sonografik olarak ayırtedilebilmesi için gerekli yeni ve objektif kriterler tespit etmeyi amaçladık.

Materyal ve Metodlar: Normal ve patolojik apendikslerin, ileumun ikinci ve üçüncü formlarının transvers ultrasonografik kesitleri üzerinde milimetrik olarak uzun çap, kısa çap, ortalama çap, dairesellik indeksi, ve çap indeksi hesaplandı.

Bulgular: Dairesellik indeksi, sirkülarite indeksi ve uzun çap, normal veya patolojik apendiksin ileal segmentlerden ayırtedilmesinde yüksek oranda sensitivite ve spesifisite gösterdi.

Sonuç: Dairesellik indeksi, sirkülarite indeksi ve uzun çap normal veya patolojik apendiksin ileumdan ultrasonografik olarak ayırtedilmesinde objektif ve etkin kriterlerdir

Anahtar kelimeler: Apendiks, apendisit, ileum,ultrason görüntüleme, tanı

Introduction

AAcute appendicitis is one of the most common diagnoses made in patients with an "acute abdomen." Although the mortality rate has been reduced, negative appendectomy rates have remained unchanged when the diagnosis is established on the basis of clinical history and physical and laboratory findings [1-5].

Cross-sectional imaging techniques, including ultrasonography (US), computed tomography (CT), and more recently, magnetic resonance imaging (MRI), have been successfully used to examine patients suspected to have appendicitis [1-15]. Because of technical improvements, US has been reported to reach sensitivities and specificities of up to 98% for diagnosis of acute appendicitis, a rate highly dependent on the experience of the sonographer [5,11-17]. However, even to experienced sonographers, the normal vermiform appendix is not always visible sonographically. With conventional US imaging, a normal appendix can be clearly identified in 12-82% of cases [16,18-21]. This rate is higher in pathologic appendices [22].

Visualization of a normal-appearing appendix by cross-sectional imaging techniques in a patient suspected to have acute appendicitis will prevent negative appendectomy and related perioperative complications, as well as late-stage complications such as chronic right-sided lower abdominal pain [23,24]. Therefore, any improvement in the detection of the appendix with US is important for reduction of unnecessary CT and MRI scans, negative appendectomy rates, and other complications.

In this study, we aimed to determine the criteria that can be used in distinguishing the normal or pathological appendix from ileal segments.

We planned this study to determine the criteria that can be used in distinguishing the normal or pathological appendix from ileal segments in patients with or without clinical suspicion of acute appendicitis.

Materials and Methods

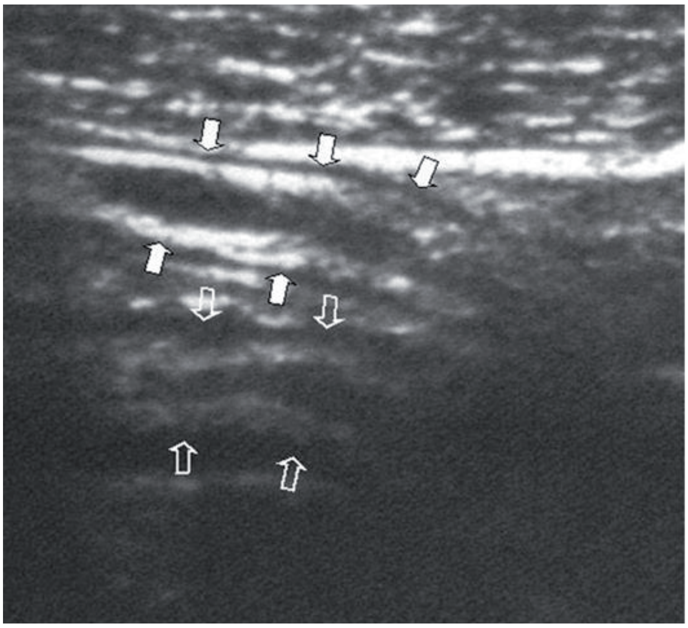
The study was performed on 292 consecutive patients who agreed to be included in the study and who presented to our department for abdominal or pelvic sonographic examination, with clinical findings of suspected acute appendicitis in 61 cases and other causes in the remainder (Table 1). Patients who were unwilling to participate or whose general condition was not suitable for extra ultrasound examination, including patients in the emergency room or intensive care unit with trauma, severe dyspnea, or shock, and patients who needed immediate operations, were excluded. Age and gender were recorded for each patient. All examinations were performed with the same ultrasound machine with a 5-13 MHz broadband matrix linear transducer (Logic 900, General Electric, Milwaukee, WI, USA). We used frequencies of 8-10 MHz for the US examinations. US was performed on each patient, once before and again after the routine abdominal or pelvic US examination with an approximately 1-hour interval, by two observers experienced in abdominal sonographic imaging. US evaluation for the visualization of the appendix was limited to 5 minutes for each patient. If the appendix could not be visualized during the 5 minutes of scanning, it was accepted as non-visualized. To find the appendix, we localized the cecum and terminal ileum, then systematically investigated the possible localizations of the appendix. We evaluated the right lower quadrant, right upper quadrant, periumbilical area, and pelvis. We observed the appendix as a blind-ending tubular structure originating from the cecum. In cases with partially visualized appendices, we always visualized the ileum separately as originating from the cecum, confirmed by either observing peristalsis in it or its larger diameter compared to the appendix. If either or both observers thought that they had found the appendix, they saved the video images onto the machine. Three experienced observers later examined each saved video image on the machine to evaluate for correct diagnosis. If the observers decided that the imaged structure was the appendix, the appendix was accepted as visualized with that method by those observers, and these patients were reevaluated by a third radiologist to determine the ileum. The diameter and localization of the appendix were recorded. Compressible appendices with diameters smaller than 6 mm were accepted as normal. Appendices that had larger diameters, were distended with fluid, and were noncompressible in cases of clinical suspicion of appendicitis were accepted as pathologic.

After the US examinations, 61 patients with clinical findings of suspected acute appendicitis were followed for two weeks after discharge, either at the hospital or by phone. Surgical and pathological results from the surgical patients and follow-up results for the nonsurgical patients were obtained, and the patients were divided into suspected normal and appendicitis groups. Both groups were also divided into subgroups of females, males, and children (Table 1).

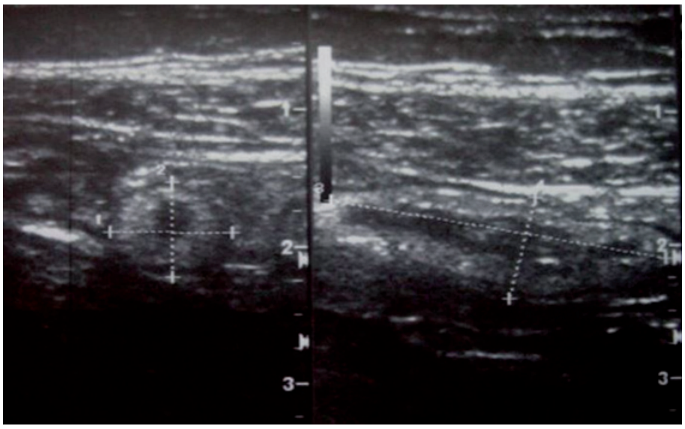
Table 1. Study case group (N: number of patients)

	Female		Male		Child	
	N	Age	N	Age	N	Age
1 Control	44	37.6 ± 13.2	26	34.2 ± 8.1	21	7.2 ±3.8
Suspected normal	2	28.0 ± 4.2	4	31.4 ± 11.1	9	7.4 ± 4.6
Appendicitis	-		1	27	5	6.2 ± 5.3
2 Control	58	39.2 ± 12.3	43	33.5 ± 12.8	39	7.0 ± 5.7
Suspected normal	7	31.4 ± 6.3	6	27.4 ± 7.2	11	6.7 ± 3.7
Appendicitis	5	26.1 ± 4.8	2	22.5 ± 4.9	9	6.9 ± 4.7
Total	116		82		94	

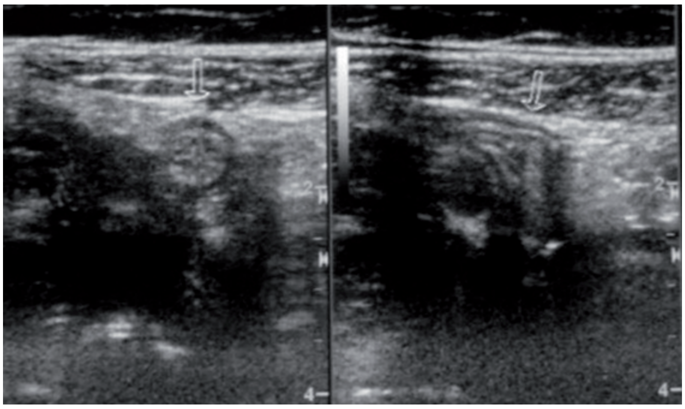
Transverse images perpendicular to the long axis of the appendix and ileum were recorded. Two measurements were made from the thick and thin regions of the appendices in which these diameters differed along the length. The ileum was observed in three different forms: actively peristalsing with the lumen filled, at a state of rest with the lumen empty, and fully contracted with the lumen disappeared (Figure 1A, B, C). Appendices were classified as normal or pathological according to the results of the operation and follow-up.



A. Active peristalsis and the lumen-filled ileum (solid white arrows), and appendix (empty white arrows) on longitudinal imaging.



B. State of rest and the empty lumen of the ileum (right image shows appendix, left image shows ileum) on transverse imaging. Dotted lines also show long and short diameters of the appendix and ileum.



C. Fully contracted and disappeared lumen of the ileum (right image arrow indicates appendix, left image arrow indicates ileum).

Statistical analysis

Long diameter (L), short diameter (S), mean diameter (M), circularity index (CI: L / S), and diameter index (DI: C [L + S]) on transverse images of normal and pathological appendices, and the second and third forms of the ileum, were calculated (Table 2, Figure 1B). The cutoff values were calculated with the ROC curves at the end of the first phase of 112 patients examined. These values were used for evaluation of the 180 patients in the second phase. First- and second-stage results were compared with chi-square tests separately by each observer.

Table 2. Measurements of ileum and appendix. L (long diameter), S (short diameter), CI (circularity index), DI (diameter index) in mm.

	Normal appendix	Pathologic appendix	Relaxed ileum	Contracted ileum
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Long diameter	6.2 ± 1.5	9.7 ± 2.5	16.7 ± 3.1	8.5 ± 1.3
Short diameter	4.9 ± 1.4	8.8 ± 2.1	5.4 ± 1.7	7.6 ± 1.2
Mean diameter	5.5 ± 1.3	9.2 ± 2.2	11.1 ± 1.9	8.1 ± 1.2
CI: L / S	1.42 ± 0.94	1.11 ± 0.14	3.20 ± 0.93	1.12 ± 0.13
DI: C (L +S)	14.7 ± 5.2	20.5 ± 6.5	72.2 ± 25.2	18.2 ± 3.2

Results

The findings are summarized according to both observers in the two phases in Table 3. A total of 166 appendices were identified, 56 of which had two separate measurements. For the second form of the ileum, a total of 156 units were identified, 57 in the first stage and 99 in the second stage. A total of 114 units of the third form of the ileum were found. At the end of the first phase, the cutoff value for the DI was 33 mm, with 100% sensitivity and specificity, and the cutoff value for the CI was 2.3 mm, with 96.7% (76/80) sensitivity and 96.4% (55/57) specificity, in discrimination of the appendix from the second form of the ileum. In the whole study group, the 33-mm cutoff value for the DI showed 98.6% (219/222) sensitivity and 98.7% (154/156) specificity, and the 2-mm cutoff value for the CI showed 92.7% (206/222) sensitivity and 98.0% (153/156) specificity in discrimination of the appendix from the second form of the ileum. The 1.7-mm cutoff value for the CI showed 100% sensitivity and specificity in discrimination of the pathological appendix from the second form of the ileum, and the 10.6-mm cutoff value for the long dimension showed 98.6% (219/222) sensitivity and 96.7% (151/156) specificity in discrimination of the normal appendix from the second form of the ileum.

Table 3. The findings according to observers, and stages.

			First observer		Second observer
Phase 1	Control		91	48 (52.7)	38 (41.7)
	Suspected normal		15	7 (46.6)	6 (40.0)
	Appendicitis		6	6 (83.3)	5 (83.3)
Phase 2	Control		140	73 (53.5)	70 (50.0)
	Suspected normal		24	18 (75.0)	11 (45.89)
	Appendicitis		16	14 (87.5)	13 (81.2)
	Total		180	105 (58.3)	94 (52.2)
Total			292	165 (56.5)	143 (45.5)

All measurements showed a low success rate in distinguishing normal and pathological appendices from contracted ilea, and contracted ilea demonstrated peristaltic activity in about 4 seconds. In differentiating normal and pathological appendices, CI ($p<0.001$) and DI ($p=0.011$) were observed with significantly different values. In investigating the appendix, $p=0.391$ for DI and $p=0.441$ for CI, and in examining the ileum, $p=0.895$ for DI and $p=0.220$ for CI were observed.

Observers 1 and 2 used the index criteria for appendix and ileum distinction, staying at a total of 12 suspected cases (5 and 7, respectively). The appendix was followed in 4 of these patients and the ileum was followed in 8. Two of the 4 appendix patients showed pathological appendices and were operated on. In the 8 ileum patients, the appendix was revealed in 3 of them on the second examination. The appendix-detection rate in the second phase significantly increased for the first observer (53.3% in the first phase and 58.3% in the second phase [$p=0.027$], compared to 43.7% in the first phase and 52.2% in the second phase for the second observer [$p=0.356$]).

Discussion

To our knowledge, there has been no study to determine the criteria for distinguishing a normal or pathological appendix from ileal segments in patients with or without clinical suspicion of acute appendicitis.

The diagnosis of acute appendicitis established on the basis of clinical history and physical and laboratory findings results in an overall accuracy of approximately 80%, with a negative-appendectomy rate of approximately 20%. Investigators in prior studies have reported that negative appendectomy rates vary by patient sex, with a range of 5-16% in men and 11-34% in women [1-5]. These sex-based differences reflect the fact that the diagnosis of appendicitis differences reflect the fact that the diagnosis of appendicitis on a clinical basis alone may be extremely difficult in female patients because of the broad overlap of symptoms of acute gynecologic abnormalities. Recent reports reveal that with the advent of CT, US, and MRI, accuracy and the rate of normal-appendix removal improved significantly, particularly in patients with atypical symptoms. It is also reported that the population of patients that benefits the most from preoperative imaging is women. With CT and US imaging, negative appendectomy rates decreased to 7-11% from 28-34% in this patient population [1,4]. In general, CT has been accepted as superior to US in the diagnosis of appendicitis, with higher sensitivity, specificity, and accuracy, and lower normal-appendix removal. The sensitivity, specificity, and accuracy of CT imaging were reported as 93-100%, 85-99%, and 94-97.6%, respectively, with higher ratios in men compared to women [5-10]. The corresponding values for US imaging shows wide range: 50-99.3%, 68.1-98%, and 83-98%, respectively, with higher rates in examinations performed by highly qualified sonographers [5,11-15]. These rates were higher when only the visible appendices were included in statistical evaluations [16]. Due to technical improvements, sonography has been reported to reach sensitivities and specificities of up to 98% for the diagnosis of acute appendicitis, a rate highly dependent on the experience of the sonographer [25,26]. Visualization of the appendix depends not only on the experience of the observer but also on certain patient-related factors, such as obesity, bowel gas, atypical position of cecum, or retrocecal position of appendix [13,14,17]. To improve the visualization of the appendix, hydrocolonic US, a method applied with saline enema, has been used. This technique increased sensitivity of US imaging from 50% to 75% [5]. The posterior manual compression technique is another method that increased the ratio of appendix visualization from 85% to 95% [18].

The normal appendix can be visualized in approximately 12-82% of patients [16, 18-21]. In inflamed appendices, this rate increases to up to 95% [22]. However, acute appendicitis can be found in a remarkable number of patients with non-visualized appendices [16].

Visualization of the normal appendix is important in preventing normal-appendix removal and related perioperative and postoperative complications, most commonly infections and chronic right lower quadrant pain [23,24]. A finding of a normal appendix strongly argues against the decision to operate on patients with positive clinical findings in the absence of other surgical conditions.

There is a marked overlap of outer appendiceal diameters in normal and acutely inflamed appendices. The cutoff point of 6 mm or more for the outer appendiceal diameter as a US criterion to confirm acute appendicitis provides high sensitivity but limited specificity. The cutoff point of 7 mm or more provides a higher accuracy, but it may cause cases of acute appendicitis to be overlooked. As a diagnostic criterion, the outer appendiceal diameter is more useful in excluding acute appendicitis than in confirming its presence [27]. In addition, as a special exception, the outer appendiceal diameter is not at all reliable as a diagnostic aid in a population of patients with cystic fibrosis, even as a minor criterion [28].

Another probable reason for the high detection rate in previous reports is that sonography was performed only in patients with abdominal pain, not in healthy subjects. Rettenbacher et al. [29] reported that the detection rate in symptomatic patients without appendicitis (77%) was higher than that in subjects with a normal appendix (68%). For example, patients with digestive problems (such as enteritis and diverticulitis) often have decreased intestinal gas (due to dilatation or edema of the bowel, fluid collection, or hyperplastic mesentery), whereas patients with constipation or any other relevant condition have accumulation of intestinal gas. In many cases, therefore, changes associated with abdominal pain may facilitate visualization of the appendix. Wiersma et al. [30] found that in pediatric subjects, a normal appendix was depicted more frequently than in adults, possibly because there is less attenuation of the ultrasonic beam by subcutaneous fat and muscle, which are thinner in pediatric subjects [31].

Numerous pitfalls exist that may deceive radiologists, resulting in a missed diagnosis of appendicitis. Pitfalls leading to a false-negative sonographic diagnosis of acute appendicitis include appendicitis confined to the appendiceal tip, retrocecal appendicitis, gangrenous or perforating appendicitis, a gas-filled appendix, and a markedly enlarged appendix. Pitfalls leading to a false-positive sonographic diagnosis of acute appendicitis include resolving appendicitis, a dilated Fallopian tube mimicking appendicitis, the muscle fibers of the psoas mimicking an appendix, periappendicitis from surrounding inflammation, and inspissated stool mimicking an appendicolith [32,33].

The inflamed appendix may be unusual in its location, or may appear normal if only a small portion of the distal appendix is involved (tip appendicitis). In a patient with a history of appendectomy, inflammation of the appendiceal stump may be easily missed. Appendicitis may closely mimic small bowel obstruction or gynecological disease, especially after perforation has occurred. Even a misleading clinical history may lead the radiologist's eye astray [34].

An ovoid shape over the entire length of the vermiform appendix is a useful US criterion, since it helps to reliably rule out acute appendicitis. A round appendix indicates acute appendicitis with a sensitivity of 100%, specificity of 37%, positive and negative predictive values of 50% and 100%, respectively, and accuracy of 61% [29].

There is a need for new criteria in all of these cases because of the difficulty of identification of normal and abnormal appendices and their discrimination from ileal segments.

Conclusion: Consequently, the cutoff value of 33 mm for DI and 2 mm for CI had a high sensitivity and specificity in discrimination of the appendix from the ileum. At the DI cutoff value of 33 mm, there was 98.6% sensitivity and 98.7% specificity, and at the CI cutoff value of 2 mm, there was 92.7% sensitivity and 98.0% specificity in discrimination of the appendix from the second form of the ileum in the whole study group. These criteria seem to shorten the examination time for the evaluation of the appendix, especially for children, as well as when the superposition of intestinal gas obscures the ileal segments and the visualization of the appendix.

Although the shape of the appendix and the outer diameter of the appendix (Rettenbacher 2001et al. and 2003 et al.) have been established as highly useful criteria for diagnosing or excluding appendicitis, in the current study we present new objective criteria for the diagnosis of appendicitis. These criteria result in less time being necessary for diagnosis, and seem to be more objective than in previous studies.

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