



THE EFFECTS OF AGE, SEX, AND BODY MASS INDEX ON THE DETECTION OF APPENDIX SONOGRAPHICALLY

Apendiksin sonografik olarak değerlendirilmesinde yaş, cinsiyet ve vücut kitle indeksinin etkisi.

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ABSTRACT

Sonographically visualising the normal appendix precludes unnecessary examination and may reduce negative appendectomy rates. In addition, the appendix cannot always be displayed successfully with ultrasonography (US). In this study, we aimed to investigate the effects of age, sex, and body mass index (BMI) on the detection of a normally vermiform appendix by US.

The study included 173 patients who applied for routine US examinations with no clinical findings of appendicitis. Age, BMI (only in adult patients), and gender were recorded. We searched for the appendix in each patient using both tissue harmonic imaging (THI) and conventional US after the routine US examinations. When the appendix was found, localisation and diameter were recorded. The two methods were compared in all patients, and the relation between the rate of visualisation and BMI was determined.

The appendix was found in 59% of the patients: 50% of women, 41% of men, and 93% of children. Statistically, the detection rate was significantly higher in children. The ratios of visualisation in patients with BMIs <25 were 55% in females and 56% in males. In patients with higher BMIs, the ratios were 46% and 29%, respectively. Considering male and female patients together, the ratios were 55% in patients with BMIs <25 and 40% in patients with higher BMIs. There was a significant difference in the appendix detection rate between observers using the two imaging techniques.

There are differences between observers when detecting the appendix, and there is a significant correlation between appendix visualisation and BMI. THI visualises the appendix better than conventional US does. THI and conventional US are more successful in children than in adults, and in detecting pathological appendices than normal appendices in all groups.

Key words: Appendix, appendicitis, tissue harmonic imaging, ultrasound and BMI.

ÖZET

Apendiksin sonografik olarak gösterilmesi gereksiz incelemelerin önüne geçer ve negatif apendektomi oranlarını azaltabilir. Ayrıca apendiks her zaman ultrasonografi (US) ile başarılı bir şekilde gösterilemeyebilir. Biz bu çalışmada yaş, cinsiyet, Beden Kitle İndeksi'nin (BKİ), normal vermiform apendiksin US ile saptanmasına olan etkilerini araştırmayı amaçladık.

Çalışmaya klinik olarak apandisit bulgusu olmayan, rutin US incelemesi için başvuran toplam 173 hasta dahil edildi. Hastaların yaş, BKİ (sadece erişkin hastalarda) ve cinsiyetleri kaydedildi. Rutin US incelemesinden sonra, her hastada doku harmonik görüntüleme ve konvansiyonel US ile apendiks araştırıldı. Apendiks bulunduğu zaman lokalizasyon ve çapı kaydedildi. Tüm hastalarda her iki yöntem karşılaştırıldı ve apendiksin görülme oranı ile BKİ arasındaki ilişki tesbit edildi.

Apendiks hastaların 59%'unda tesbit edildi; kadınlarda 50%, erkeklerde 41%, çocuklarda 93% oranında gösterildi. Apendiksin gösterilme oranı çocuklarda istatistiksel olarak yüksekti. BKİ 25'ten küçük olan hastalarda apendiksin izlenme oranı kadınlarda 55%, erkeklerde 56% idi. BKİ daha yüksek olanlarda bu oranlar sırasıyla, 46% ve 29% şeklindeydi. Kadın ve erkekler birlikte düşünüldüğünde BKİ 25'ten küçük olan-

larda bu oran 55%, BKİ daha büyük olanlarda ise 40% şeklindeydi. Her iki inceleme tekniğini kullanan gözlemciler arasında apendiks tespit oranı açısından anlamlı bir fark izlendi.

Apendiks tespit edilmesi açısından gözlemciler arasında belirgin farklar mevcuttur. Ayrıca, BKİ ile apendiks izlenmesi arasında anlamlı korelasyon tespit edilmiştir. Doku harmonik görüntüleme konvansiyonel US'ye göre apendiksi daha iyi göstermektedir. Doku harmonik görüntüleme ve konvansiyonel US tüm gruplarda patolojik apendiks normal apendiksdan ayrımında oldukça faydalıdır.

Anahtar kelimeler: Apendiks, apandisit, doku harmonik görüntüleme, ultrason ve BKİ

INTRODUCTION

Acute appendicitis is one of the most common diagnoses made in both adults and children with an "acute abdomen". Although the mortality rate has been reduced, negative appendectomy rates of 5–34% have remained unchanged when the diagnosis is established on the basis of clinical history and physical and laboratory findings (1-5, 6).

Cross-sectional imaging techniques, including ultrasonography (US), computed tomography (CT), and more recently, magnetic resonance imaging (MRI) which should be the first-line imaging test in pregnant women have been used successfully to examine patients suspected of having appendicitis (1-5,7-16, 17). Due to technical improvements, sonography has been reported to reach sensitivities and specificities of up to 98% in diagnosing acute appendicitis, a ratio highly dependent on the experience of the sonographer (5, 12-16,18,19). However, the normal vermiform appendix is not always visible sonographically, even to experienced sonographers. With conventional US imaging, a normal appendix can be clearly identified in 12-82% of cases (18, 20-23); the ratio is higher in pathological appendices (24).

Visualisation of a normal appearing appendix by cross-sectional imaging techniques in patients suspected of acute appendicitis helps prevent negative appendectomy rates and related perioperative and late-stage complications, such as chronic right-sided lower abdominal pain (25, 26). Therefore, any improvement in the detection of appendices with US is important for reducing unnecessary CTs and MRIs, as well as negative appendectomy rates and other complications.

Harmonic imaging, originally developed as a contrast imaging technique, is now widely used in native tissue imaging, or tissue harmonic imaging (THI). Low-amplitude harmonic waveforms are generated by the interaction of the tissue with the ultrasound pulse (27). Preferential display of the harmonic signal can significantly improve image quality, due to a decrease in image-degrading echoes from the body wall and echoes generated by side lobe artefacts. THI has been reported to improve overall image quality and lesion characterisation in abdominal and pelvic imaging (28-30).

The aim of this study was to identify the effects of age, sex, and body mass index (BMI) on visualising the normal vermiform appendix using

US by comparing the efficacy of conventional US versus THI in detecting the appendix.

MATERIAL AND METHOD

The study included 173 consecutive patients who underwent abdominal or pelvic sonographic examinations in our department with no clinical findings of acute appendicitis. Ninety of the patients were women, 39 were men, and 44 were children. Patients who were unwilling to participate were excluded, as were patients with general conditions not suitable for extra US examination, such as emergency room or intensive care unit patients with trauma, severe dyspnoea, or shock, or patients requiring immediate surgery. The age and gender of each patient was obtained, and BMI was calculated [weight (kg)/height (m)²] in the adult patients. All examinations were performed using the same US machine, which had a 5-13 MHz broadband matrix linear transducer (Logic 900; General Electric, Milwaukee, WI). Frequencies of 8-10 MHz were used for conventional US and 5 and 10 MHz were used as transmitted and received frequencies, respectively, for THI. Both conventional US and THI were performed on each patient after the routine abdominal or pelvic US examination. The tests were conducted in two phases (THI first and conventional US second) by two observers experienced in abdominal sonographic imaging.

To find the appendix, the cecum and terminal ileum were localised first, and then the possible localisations of the appendix were systematically investigated, evaluating the right lower quadrant, right upper quadrant, periumbilical area, and pelvis. The appendix was observed as a blind ending tubular structure originating from the cecum. In cases with a partially visualised appendix, the ileum was visualised originating separately from the cecum, confirmed by observing either peristalsis in it or a larger diameter compared to the appendix. If either or both observers thought the appendix had been found, the video images were saved onto the machine. The observers then came together and examined each saved video image on the machine. If the observers decided that the imaged structure was the appendix, the appendix was accepted as visualised by that method by that observer. If they decided that it was not the appendix, they accepted that the appendix was not visualised. Diameter and localisation of the appendix were recorded. Compressible appendices with diameters smaller than 6 mm were

accepted as normal. Appendices with larger diameters, distended with fluid, and non-compressible, with clinical suspicion of appendicitis, were accepted as pathological. All groups were divided into women, men, and children.

The results of the THI and conventional US imaging were compared for success rates with the McNemar test in all patients and in the women, men, and children groups separately. One hundred and seventy-three patients without clinical findings of acute abdomen who were evaluated using both methods were also tested with the McNemar test to assess the power of the method.

The children were compared with the adult population as a different group for both methods, using Pearson's Chi-square test. The effectiveness of both methods in the 173 cases were made with Pearson's Chi-Square test for conventional US and with Fisher's exact test for THI. The relation between visualisation of appendix and BMI was determined with Pearson's Chi-square test. $P < 0.05$ was accepted as statistically significant for all tests.

RESULTS

The characteristics (age, gender, and BMI) of the patients in each group are summarised in Table 1. When all the patients were taken into account, there were no age difference between the female and male groups (female group, age 40.5 ± 10.5 years; male group, age 43.1 ± 13.3 years; $p < 0.05$). There were no statistically significant differences between the sexes ($p < 0.05$).

The results of the US evaluations of the groups are summarised in Table 2. Appendices were seen in 102 total patients (59%), 50% of the women, 41% of the men, and 93% of the children; the detection rate was significantly higher in children statistically.

Appendix detection rate was statistically lower in patients with BMIs ≥ 25 compared to patients with BMIs < 25 . The ratio was higher in women than in men, but this difference was not significant. The ratios were 46% in BMI ≥ 25 and 55% in BMI < 25 in women, and 29% and 56%, respectively, in men. There was a significant correlation between BMI and visualisation of appendix. The ratio of visualisation in patients with BMIs < 25 was 55% in women and 56% in men. In patients with higher BMIs, these ratios were 46% and 29%, respectively. The ratio in total patients with BMIs < 25 was 55%, and in patients with higher BMIs, the ratio was 40% (Table 2). The ratio of visualisation of the entire length of the appendix in patients with BMIs < 25 was 50% in both women and men; in patients with higher BMIs, the ratios were 28% and 24%, respectively (Table 3). Visualisation of the entire length of the normal appendix was found to be more successful with THI compared to conventional US (Figure 1).

Both methods (THI and conventional US) were found to be successful in children compared to the adult groups. In the paediatric patients, the first observer's investigations resulted in $p < 0.001$ for THI and $p < 0.001$ for conventional US, and the second observer's investigations resulted in $p = 0.022$ for THI and $p < 0.001$ for conventional US. Both observers detected pathological appendices more successfully than normal ones using both methods (first observer, THI $p < 0.001$ and conventional US $p < 0.001$; second observer, THI $p < 0.001$ and conventional US $p < 0.001$) (Figure 2). There were significant differences in the appendix detection rate between observers with both imaging techniques (THI $p < 0.001$ for the first and second observer and conventional US $p < 0.001$ for the first and second observer).

Table 1: Study case groups with BMI, age, and gender correlations (BMI= Body Mass Index).

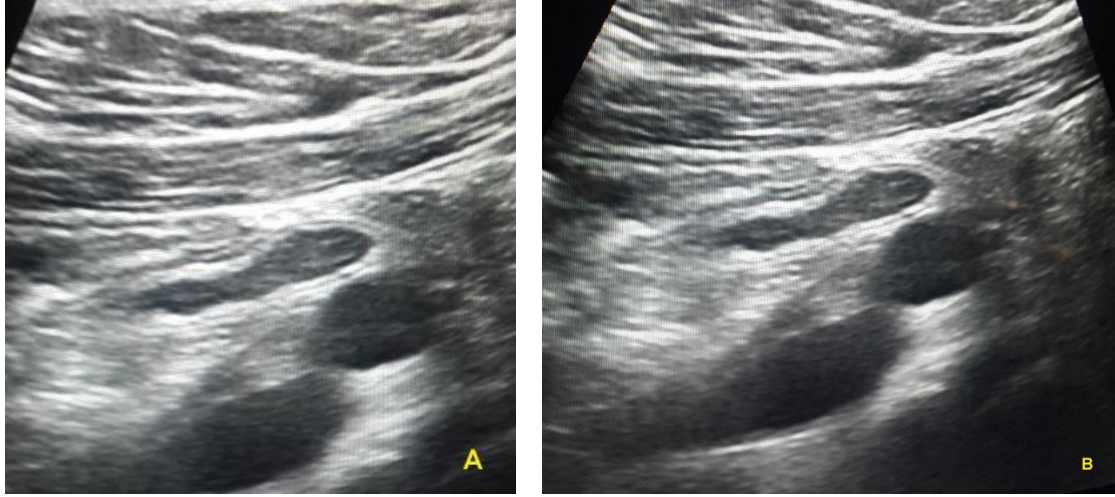
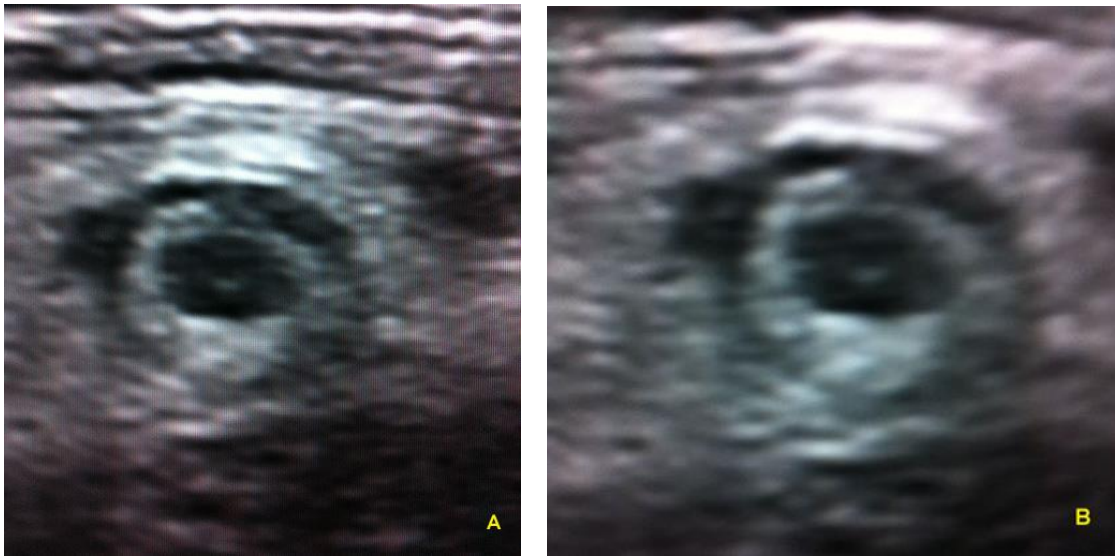
| | Women | Men | Children |
|---------------|----------------------------|----------------------------|---------------------------|
| Total | 90 | 39 | 44 |
| BMI < 25 | 44 | 18 | |
| BMI ≥ 25 | 46 | 21 | |
| Age | 40.5 ± 10.5 18–72 y | 43.1 ± 13.3 19–73 y | 8.2 ± 3.9 1 M–15 y |

Table 2: Results of ultrasound evaluation by group (women, men, and children) with BMI correlation

| | N | Total | N | BMI < 25 | N | BMI ≥ 25 |
|----------|-----|-----------|----|------------|----|---------------|
| Women | 90 | 45 (50%) | 44 | 24 (55%) | 46 | 21 (46%) |
| Men | 39 | 16 (41%) | 18 | 10 (56%) | 21 | 6 (29%) |
| Children | 44 | 41 (93%) | | | | |
| Total | 173 | 102 (59%) | 62 | 34 (55%) | 67 | 27 (40%) |

Table 3: Results of ultrasound evaluations of appendix visualisation for its whole lengthwise by group (women, men, and children) with BMI correlation.

| | N | Total | N | BMI <25 | N | BMI ≥25 |
|----------|-----|----------|----|----------|----|----------|
| Children | 44 | 34 (77%) | | | | |
| Women | 90 | 35 (39%) | 44 | 22 (50%) | 46 | 13 (28%) |
| Men | 39 | 14 (36%) | 18 | 9 (50%) | 21 | 5 (24%) |
| Total | 173 | 83 (48%) | 62 | 34 (55%) | 67 | 27 (40%) |

**Figure 1:** THI (A) and conventional US (B) images of a normal appendix showing the slightly better image quality of THI.**Figure 2:** THI (A) and conventional US (B) images of a pathological appendix showing adequate image quality of both imaging methods.

DISCUSSION

To the best of our knowledge, there are no studies in the literature comparing conventional US and THI in appendix detection with BMI correlation.

The diagnosis of acute appendicitis established on the basis of clinical history and physical and laboratory findings results in an overall accuracy

rate of approximately 80%, with a negative appendectomy rate of approximately 20%. Investigators in prior studies have reported that negative appendectomy rates varied by the sex of the patient, with a range of 5-16% in men and 11-34% in women (1-5). These sex-based differences reflect the fact that

diagnosing appendicitis on a clinical basis alone may be extremely difficult in female patients because of the broad overlap of symptoms of acute gynaecologic abnormalities. Recent reports have shown that with advent of CT, US, and MRI, accuracy rate and incidence of normal appendix removal improved significantly, particularly in patients with atypical symptoms. It has also been reported that the population of patients that benefits most from preoperative imaging is women. With CT and US imaging, negative appendectomy rates have decreased from 28-34% to 7-11% in this patient population (1, 4). In general, CT has been accepted as superior to US in diagnosing appendicitis, with higher sensitivity, specificity, and accuracy and lower rate of normal appendix removal. The sensitivity, specificity, and accuracy of CT imaging have been 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 a wider range: 50-99.3%, 68.1-98%, and 83-98%, respectively, with higher ratios in examinations performed by highly qualified sonographers (5, 12-16). These ratios were higher when only the visible appendix was included in statistical evaluations (18).

Visualisation of the appendix depends not only on the experience of the observer, but also on some patient-related factors, such as obesity, bowel gas, atypical position of the cecum, or retrocecal position of the appendix (14,15,19). To improve visualisation of the appendix, hydrocolonic US, a method applied with a saline enema, has been used. This technique increased the sensitivity of US imaging from 50% to 75% (5). Posterior manual compression is another method that has been reported to increase the ratio of appendix visualisation, from 85% to 95% (20).

The normal appendix can be visualised in approximately 12-82% of patients (18,20-23). In inflamed appendices, this ratio increases up to 95% (24). On the other hand, acute appendicitis can be found in a remarkable number of patients with unvisualised appendices (18).

Visualisation of the normal appendix is important in preventing normal appendix removal and related perioperative and postoperative complications, the most common of which are infections and chronic right lower quadrant pain (25, 26). Finding a normal appendix is strongly against the decision of operation in patients with positive clinical findings in the absence of other surgical conditions.

THI is a sonographic technique that can potentially provide images that are higher in quality than conventional sonographic techniques. Harmonics, which are frequencies generated by the propagation of the ultrasound beam through tissue, occur at multiples of the fundamental or transmitted sonographic frequency. THI sonography uses these harmonic frequencies to produce a sonogram rather than using the frequency spectrum transmitted to the

patient in conventional US (27). Imaging using harmonic frequencies offers several potential advantages, including improved lateral resolution and fewer side-lobe artefacts. Increased lateral resolution improves the ability to resolve small anatomic structures and detail. Reduction in side-lobe artefacts improves the signal-to-noise ratio, resulting in an image in which tissues appear brighter and cavities appear darker. Because the harmonic signal is generated within the tissue, artefacts from the body wall may be less pronounced with THI. Most studies comparing the evaluation of abdominal pathologies with THI and conventional US have revealed improved image quality, lesion detection, and characterisation (particularly fluid-solid differentiation) with THI (28, 29). In a study performed with hepatic lesions, Hann et al. reported that THI had a significant impact on clinical decision-making in 10% of the patients, mostly due to the detection of additional lesions or differentiation of small cystic lesions from solid masses. They observed an improvement for both near- and far-field image quality with THI (28). Shapiro et al. similarly stated that THI penetrated better than conventional US in imaging pancreas pathologies (29). Oktar et al. concluded that THI was significantly superior for revealing stone diseases, liver cysts, gallbladder polyps, and uterine myomas, as well as overall image quality, lesion conspicuity, and elimination of artefacts (30).

We performed this study to compare conventional US and THI in appendix detection with BMI correlation. We observed a significantly higher ratio of appendix visualisation with THI than with conventional US in the adult population, especially when investigating the entire length of the appendix in 49 patients (Table 3). In all of those patients, we observed that far-field image quality was superior with THI, a finding that supports the results of Hann et al. and Shapiro et al. (28, 29). Even though the distance between the appendix and the skin is greater in adult patients and the penetration of THI is shorter, THI is still better for appendix visualisation.

We surmised that unsuccessful examinations were mostly due to a retrocecal position of the appendix. Grunditz et al. found retrocecal appendices in 17% of operated cases in their series, which consisted of 247 patients (31). It was possible to visualise the entire length of the appendix more successfully with THI than with conventional US, which could be important when diagnosing cases of focal appendicitis. Although there are different studies on this subject in the literature (32, 33), we found a significant correlation between appendix visualisation and BMI in our adult patients, which was valid for both imaging methods and was consistent with the result of Josephson et al. (34).

Technical aspects affecting the ability of the sonographer to achieve adequate compression of the right lower quadrant, such as obesity, severe pain or abdominal guarding, excessive bowel gas, or an

uncooperative patient can be listed as limitations of the study. Another limitation is the exclusion of patients unwilling to participate and patients with general conditions not suitable for extra US examination, such as emergency room or intensive care unit patients with trauma, severe dyspnoea, or shock, and patients requiring immediate surgery. Because we included consecutive patients, the number of appendicitis cases was low, which was also a limitation. Moreover, the preponderance of pelvic examinations in women led to a low number of male patients compared to female patients.

We conclude that THI better visualises the appendix in adult male, adult female, and paediatric patients, and that it successfully visualises the entire length of the appendix. THI is a simple, time- and cost-effective method, which we believe will reach the success rates of CT and will eliminate the need for further diagnostic imaging. THI and conventional US are more successful in children than in men and women, and in detecting pathological appendices than normal appendices in all groups. There are differences in appendix detection between observers. Consequently, detection of the normal appendix may help prevent negative appendectomy rates, and detection of the pathological appendix can increase success rates. Lastly, there is a significant correlation between appendix visualisation and BMI.

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