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ORIGINAL ARTICLE

Evaluation of the normal appendix at low-dose non-enhanced spiral CT

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PURPOSE
To evaluate the frequency of visualization, thickness and location of the normal appendix at non-enhanced spiral computed tomography (CT).

MATERIALS AND METHODS
Low-dose spiral CT scans obtained for renal colic assessment in 243 patients were retrospectively reviewed. The frequency of visualization, thickness and location of normal appendices were recorded without knowledge of the patients' history for the appendectomy.

RESULTS
Forty of 234 patients had a past history of appendectomy (17%). Sensitivity, specificity, positive and negative predictive values, and accuracy of visualization of the normal appendix were 71%, 85%, 96%, 37% and 73%, respectively. When no intraluminal content was visualized, this area was excluded from the measurement and the mean thickness was 3.4 mm±0.66.

CONCLUSION
The normal appendix is frequently seen at non-enhanced spiral CT. Knowing the normal thickness of the appendix can help reduce false positive and false negative diagnoses of acute appendicitis when reviewing non-enhanced spiral CT.

Key words: • appendix • appendicitis • tomography, X-ray, computed

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Acute appendicitis is one of the most common causes of acute abdominal pain. Ultrasound (US) has traditionally been widely and accurately used for the diagnosis of acute appendicitis. Sonographic criteria for the diagnosis of acute appendicitis is visualization of aperistaltic, non-compressible intestinal segment arising from caecum that measures more than 6 mm in diameter. An appendicolith which leads to obstruction of the appendix can also be demonstrated with ultrasound. Doppler ultrasound might contribute for the diagnosis of the appendicitis by demonstration of increased blood flow in the wall of the appendix in non-perforated cases, and by showing loss of perfusion in perforated cases (1-8). Although there are studies which suggest that magnetic resonance (MR) imaging can be used as alternative modality to US and computed tomography (CT), the high cost/benefit ratio of this technique limits its utilization in the diagnosis of acute appendicitis (9-11). Since it is less operator dependent compared to ultrasound (US), spiral CT has been increasingly used for the assesment of the appendix and the diagnosis of acute appendicitis. Spiral CT is also much more available and less expensive compared to MR imaging. There are many studies in the literature for the CT diagnosis of appendicitis utilizing oral, rectal and intravenous contrast agents (12-17). CT criteria for the diagnosis of acute appendicitis primarily depend upon US criteria (1-3, 18). In the literature, there are only few studies which assess CT criteria of the normal appendix (12).

The aim of this study is to define the CT criteria for the diagnosis of acute appendicitis by assessing the thickness, location and frequency of visualization of the normal appendix.

Materials and methods

A total of 315 patients who were referred to CT for urolithiasis between April 2000 and November 2002 were retrospectively reviewed. Patients who had no medical records, pediatric patients and patients who were examined with different acquisition parameters compared to parameters used for urolithiasis were excluded and the remaining 234 patients (87 females and 147 males) were included in the study. The patients' age ranged between 18 and 90 with a mean of 42 years. All examinations were performed with spiral CT (HiSpeed CT/i, GE Medical Systems, Milwaukee, Wisconsin) utilizing 7 mm slice thickness, 3.5 mm interslice gap and a pitch of 2:1. In all examinations, 120 kVp and 20 mA values were selected for the image acquisition. All patients were examined in supine position, starting from the top of the kidneys to the bottom of the bladder, during one breath-hold period. No oral, rectal or intravenous contrast media were used. Images were transferred from previously recorded optical discs and were interpreted retrospectively at work stations. For image interpretation, axial source images as well as

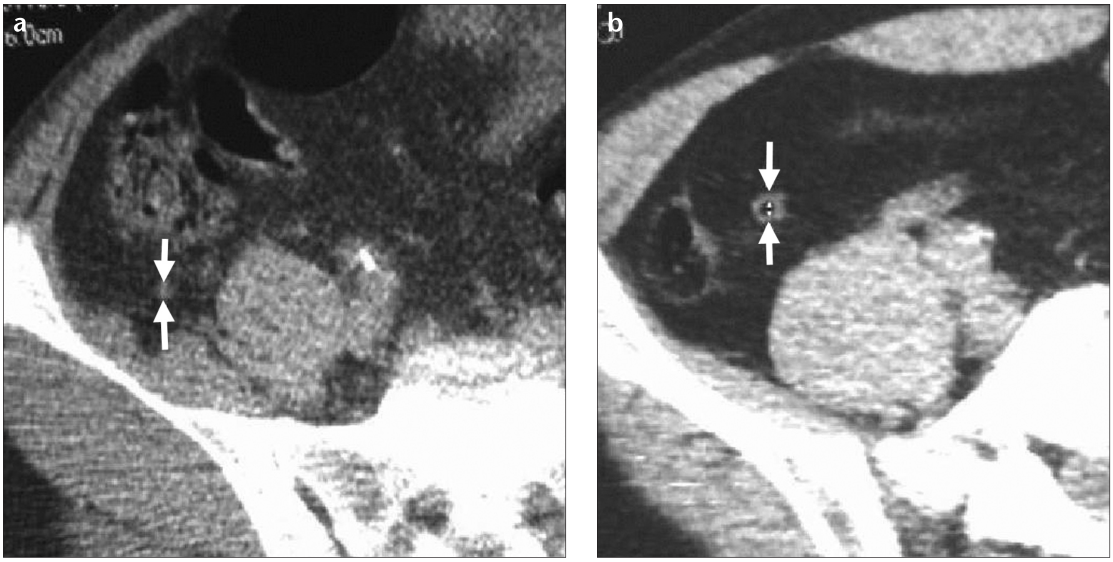


Figure1. a. The double wall thickness of the appendix in which intraluminal content was not visible is measured as 5 mm. **b.** The double wall thickness of the appendix was measured as 4 mm by subtracting the diameter of the lumen *(arrowheads)* from the full thickness of the appendix *(arrows)* in a patient whom intraluminal content can be differentiated from the wall of the appendix.

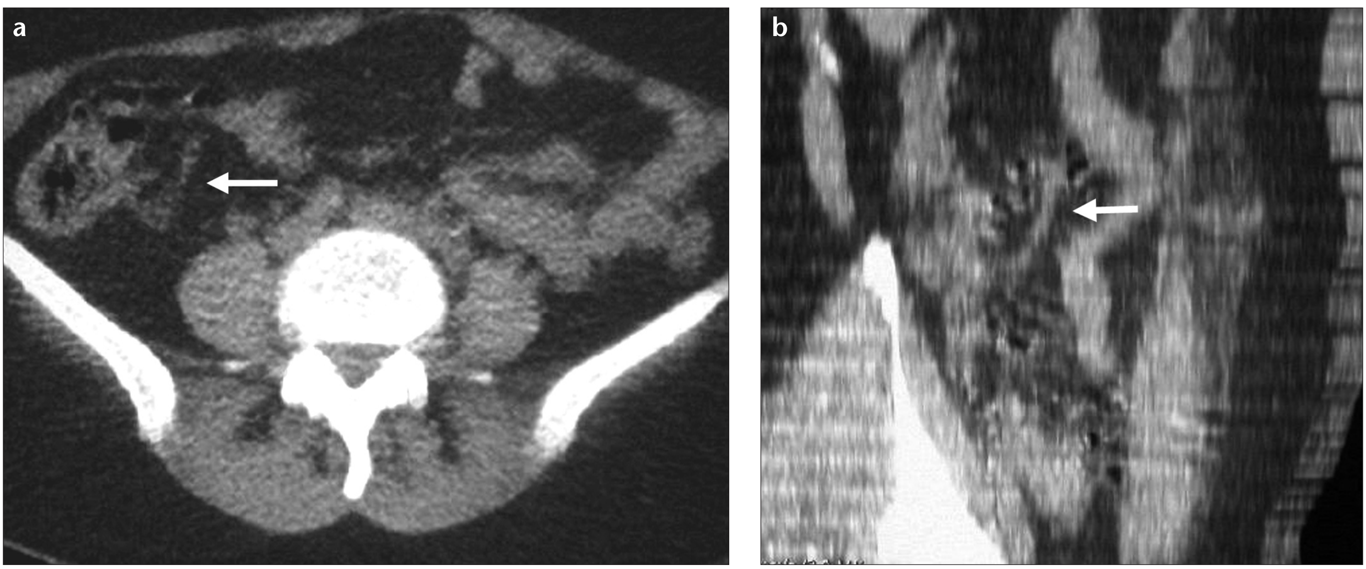


Figure 2. Axial CT section **(a)** and coronal-oblique MIP image **(b)** show an appendix located medial to the caecum *(arrow)*. Note also that the origin of the appendix and ileocaecal valve are at the same level.

multiplanar reformatted images were evaluated. Surgical history for appendectomy of each patient was searched after the completion of the interpretation of all examinations.

The visibility—whenever possible—the thickness, and the location of the appendix were noted. The rate of the visualization of the appendix was calculated for each sex and compared utilizing Fisher's exact test. Patients who had no history of appendectomy and whose appendices were visible in CT examination were classified as "true positive" and patients whose appendices were not visible classified as "false negative". Patients with a history of appendectomy in whom an anatomical structure other than appendix was misinterpreted as the appendix were classified as "false positive". Patients with a history of appendectomy in whom the appendix was not visible were classified as "true negative". The frequency of visualization of the appendix (sensitivity) in patients with no history of appendectomy; the diagnosis of missing appendix (specificity) in patients who had appendectomy, the predictive value of visualization of the appendix (positive predictive value), the prediction value of non-visualization of the appendix (negative predictive value) and accuracy rates were calculated.

If the intraluminal content could not be seen, the thickness of the appendix was found by measuring maximum double wall thickness of the appendix (Figure 1a). If intraluminal density (air-fluid) of the appendix allowed the differentiation of the wall and the lumen, the thickness was measured by subtracting the thickness of intraluminal content from double wall thickness of the appendix (Figure 1b). The location of the appendix was classified according to the position of the tip of the

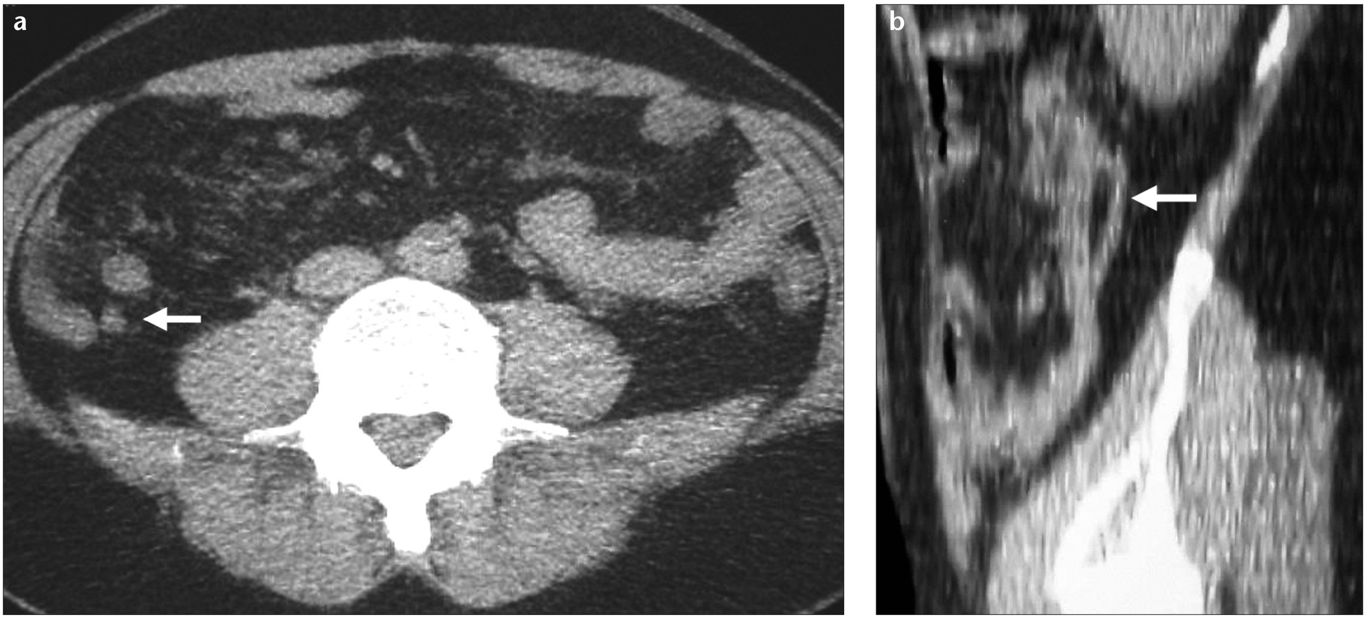


Figure 3. Axial CT section **(a)** and sagittal MIP image **(b)** show an appendix located in the retrocaecal position *(arrow)*.

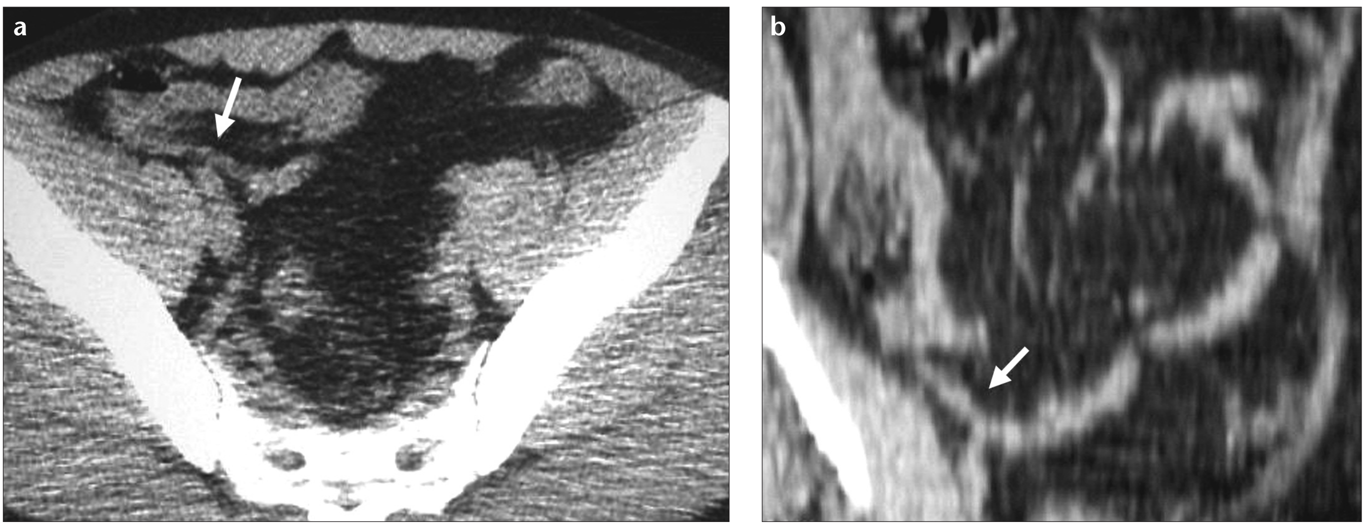


Figure 4. Axial CT section **(a)** and coronal-oblique MIP image **(b)** show pelvic position of the appendix. Axial image shows that root of the appendix and ileocecal valve are located at the same level.

appendix. If the tip of the appendix was anterior or lateral to the ascending colon, it was called "paracolic" (Figure 2); if it was posterior to caecum it was considered "retrocaecal" (Figure 3); if the tip was extending to pelvis it was called "pelvic" (Figure 4); and if it was extending to the midline without extending to pelvis it was called "midline extension" (Figure 5). The location of the appendix was also assessed according to its relation with ileocaecal valve (Figure 2a, Figure 6).

Results

Depending on information obtained from medical records and personal phone calls, the prevalence of the appendectomy was found 17.1% (40/234). There were 177 true positive, 34 true negative, 6 false positive and 57 false negative results. Depending on these values, the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and the accuracy of CT for identification of the normal appendix were 71% (137/194), 85% (34/40), 96% (137/143), 37% (34/91), 73% (171/234), respectively. In patients who had no history of appendectomy, normal appendix was identified in 64% (46/71) of the female and 73% of the male patients. No statistically significant difference was found between the genders (Fisher's exact test, p=0.088).

The mean thickness of the appendix was 3.4 mm ± 0.6 (mean ± SD) in cases in which intraluminal content was visible and 5.1 mm ± 0.25 (mean ± SD) in cases in which appendiceal content was not visible.

The most frequent locations for the tip of the appendix were paracolic in 87 patients (63.5%), pelvic in 21 patients (15.3%), retrocaecal in 17 patients (12.4%), "extending midline" in 12 patients (8.7%). Ileocaecal valve was demonstrated in 127 out of 137 (93%) patients. According to the location of the ileocaecal valve, the base of the ap-

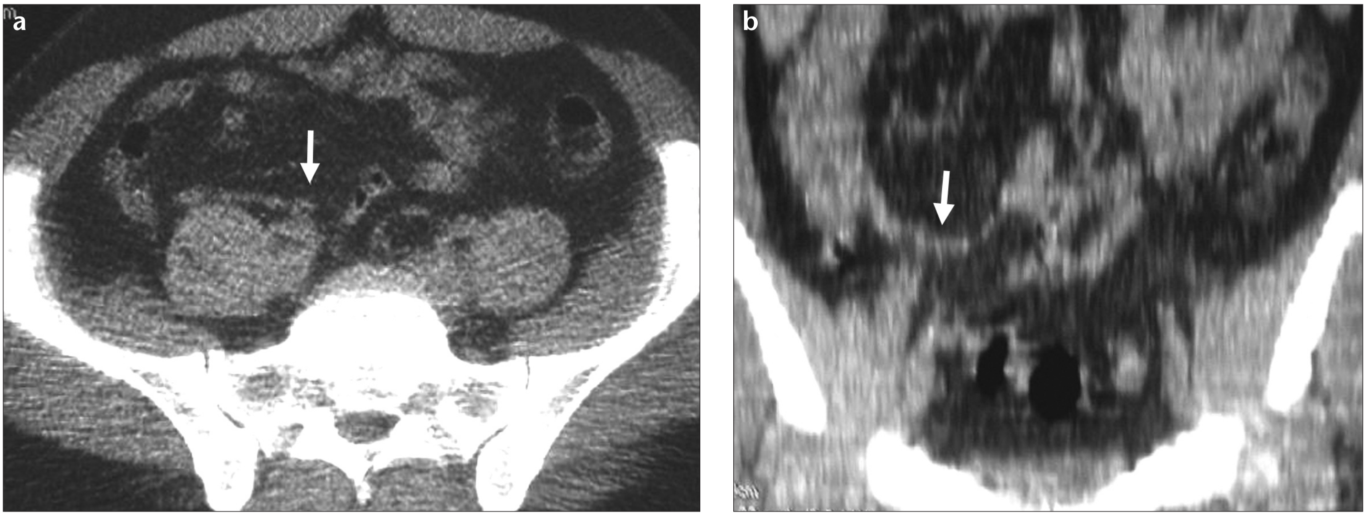
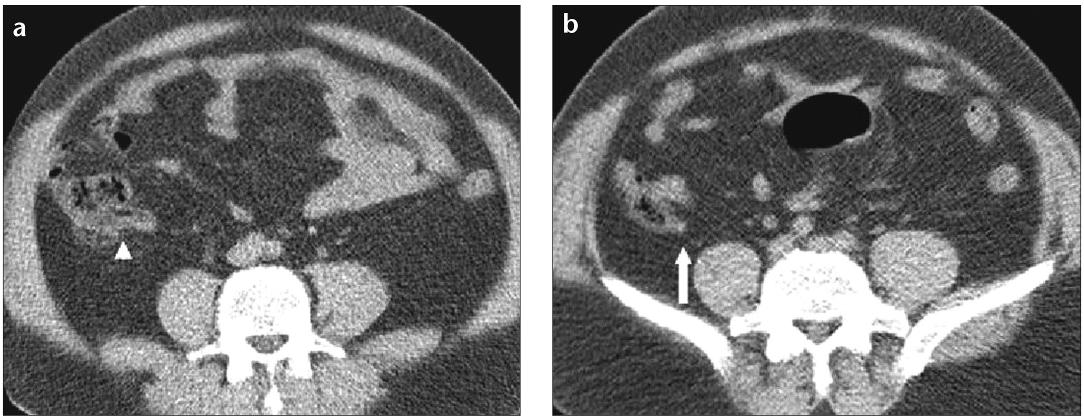


Figure 5. Axial CT section **(a)** and coronal MIP image **(b)** show an appendix *(arrow)* extending to the midline.



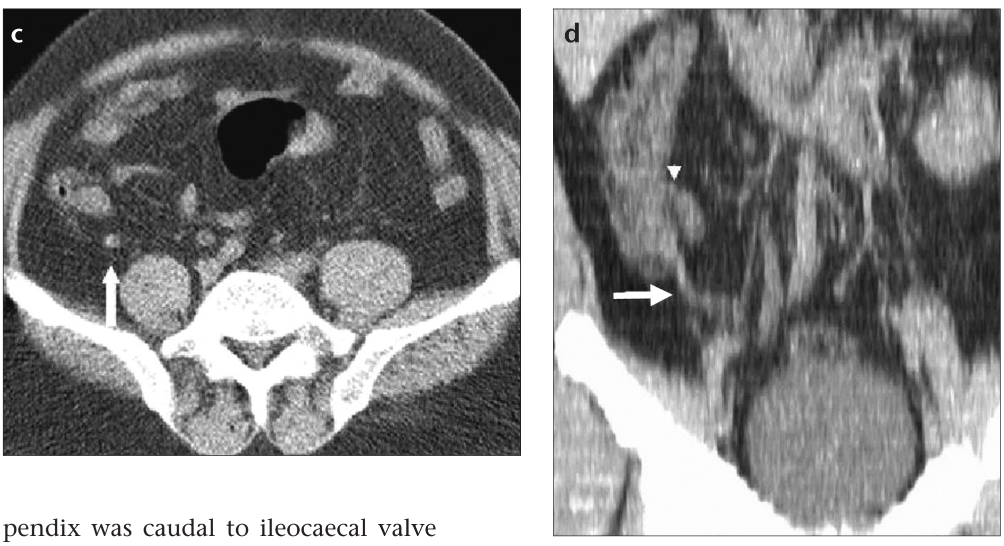


Figure 6. Axial CT sections **(a-c)**, and coronal-oblique MIP image **(d)** show that root of the appendix is located caudal to the ileocecal valve.

pendix was caudal to ileocaecal valve in 99 (78%) patients and at the same level with ileocaecal valve in 28 (22%) patients.

Discussion

Acute appendicitis is one of the most common causes of the acute abdomen and the majority of the cases can be diagnosed by history, physical examination and laboratory findings. However, it still constitutes an important problem because it can present with different clinical findings and can be confused with many diseases. There are publications suggesting that imaging methods do not have a significant contribution to the diagnosis of acute appendicitis, and that they in fact delay treatment and therefore result in increased perforation rates (19, 20). On the other hand, it is also stated that especially in atypical cases, negative appendectomy rates reaching up to

20% before the utilization of cross-sectional imaging modalities decreased to as much as 4% with the use of imaging modalities like US and CT (21, 22). There are many studies that was made with CT examinations using oral, rectal or intravenous contrast media for the diagnosis of acute appendicitis (12-17). However, especially in examinations without administration of intravenous contrast media and in cases that the luminal content of the appendix can not be seen, real double wall thickness can not be measured. Also, if it is taken into account that the appendix lumen is not always filled with either oral or rectal contrast agent, the determination of the upper limit for the appendiceal diameter in nonenhanced CT becomes more important.

CT criteria for the diagnosis of acute appendicitis include double wall thickness being more than 6-7 mm, periappendiceal inflammatory changes and demonstration of appendicoliths (12-15, 17, 23). However, in one study it was observed that 22% of the cases with appendicitis did not have periappendiceal inflammatory findings of CT (24). Cut-off values defined for the normal appendix are based on US criteria (1-3). But it should be kept in mind that it may not be accurate to use the cut-off values defined for US in CT, because in ultrasonographic investigation real double wall thickness can be measured by compression.

In our study, mean double wall thicknesses in cases with and without intraluminal content were measured 3.4 ± 0.66 mm and 5.1 ± 0.25 mm, respectively. According to these findings, it is considered that sonographically defined 6 mm cut-off value may also be used in CT examinations. However, it was reported in a similar study that the wall thickness of the normal appendix could reach up to 11 mm and was stated that especially in cases in whom the luminal content is not identified, upper limit of normal value should be accepted as 10 mm (25). Similar studies are required to determine an optimal cut-off value for the diagnosis of acute appendicitis in the absence of periappendiceal inflammatory changes. In our study, the frequency of visualization of the normal appendix (sensitivity) was found as 71% and positive predictive value for the visualization of the normal appendix was found as 96%. Among the cases in which the normal appendix was not identified at CT, 37% was the cases with appendectomy (negative predictive value). Also in 15% of the cases who had appendectomy, other anatomical structures were misinterpreted as normal appendix (specificity, 85%). In the light of the studies in the literature, these anatomical structures were considered to be either ileocolic artery or thickened Gerota's fascia (27).

Accuracy rate was calculated as 73% in our study. The results of our study in comparison with the results of the similar studies in the literature can be seen in the Table. In studies that were performed with US, the frequency of visualization of normal appendix was reported as variable rates between 0% and 82% (7).

The location according to the position of the appendiceal tip was found as paracolic in 87 (63.5%) cases, pelvic in 21 (15.3%) cases, retrocaecal in 17 (12.4%) cases and midline in 12 (8.7%) cases in our study. In a similar study, these values were reported as 62%, 19%, 10% and 8%, respectively (25). Interestingly, the similar findings obtained in both studies seem to be inconsistent with the classic knowledge assuming the most frequent location of the appendix as retrocaecal (26).

The identification of the caecum and the ileocaecal valve facilitates the visualization of the appendix mostly because of the anatomical relationship with this region (25). In our study, ileocaecal valve was seen in 127 of the 137 true positive cases (93%). Appendiceal root was seen caudal to the ileocaecal valve level in 99 (78%) of these cases and at the same level with the ileocaecal valve in 28 (22%) of the cases. In the light of these findings, first localizing the ileocaecal valve and then investigating the distal part of the caecum to the ileocaecal valve while searching for normal or inflamed appendix in a CT examination seems to be a method that will facilitate the radiologist's work to a greater degree.

Our study had some limitations. The first of these was that surgical-pathological proof could not be obtained for diagnosis verification. Another limitation was that our only way to reach surgical history of the patients was medical records and personal communication. It was possible for patients who have undergone a surgery for other reasons to be unaware of the situation that they had a concomitant appendectomy. Additionally, we ignored the possibility of congenital absence of the appendix. However, in a study it has been reported that the incidence of absence of the appendix is 1/100,000 (29). Finally, there was only one reviewer for the evaluation of the images. It should be remembered that in most of the emergent conditions in Turkey, there is only one radiologist

Table. Comparison of our study with similar studies reported in the literature

Study (reference number)	Contrast material	Technique (section thickness and gap, mm)	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Accuracy (%)
This study	CM (-)	7 and 3.5	71	85	96	37	73
Lane (2)	CM (-)	5 and 5	77	-	-	-	-
Benjaminov (25)	CM (-)	5 and 2.5	79	90	98	34	80
Grosskreautz (27)	IV and oral CM (+)	8 and 10	51	-	-	-	-
Scatarige (28)	Oral CM (+)	5 and 5	43	-	-	-	-

IV: intravenous, CM: contrast material

for the interpretation of the examinations.

In conclusion, it was shown in our study that with non-contrast spiral CT, normal appendix could usually be demonstrated. Although the double-wall thickness of the normal appendix correlates with the criteria defined for US, this observation must be confirmed with larger series. It is very important to determine the maximum thickness of the normal appendix at CT in order to diagnose acute appendicitis and to rule out other etiologies of acute abdominal pain.

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