Research Article

Acute Appendicitis with Ultrasound

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Abstract
Background: Identify ultrasonographic diagnostic criteria for faecal impaction of the appendix. The goal of this study was to identify the normal faecal-impacted appendix by ultrasound to avoid unnecessary surgery by a misdiagnosis of acute appendicitis. The purpose of the present study was to identify ultrasonographic diagnostic criteria for faecal impaction of the appendix. **Methods:**٩٠ patients who underwent ultrasonography for right lower quadrant pain. ١٠ cases were diagnosed as a normal faecal-impacted appendix. The criteria that we used to distinguish a faecal impacted appendix from acute appendicitis include preservation of the normal wall layering of the appendix, maximum mural thickness, presence of periappendiceal fat infiltration and increased blood flow in the appendiceal wall. **Results:**The maximum measured outer diameter of a normal faecal impacted appendix was ٠.٥٤–١.٠٣ cm, with a mean diameter of ٠.٦٨ cm. The maximum mural thickness ranged from ٠.٠٨ cm to ٠.٢٦ cm, with a mean thickness of ٠.١٥ cm. The normal wall layers of the appendix were preserved and no evidence was seen of periappendiceal fat infiltration in any case. No demonstrably increased blood flow in the appendiceal wall was observed**. Conclusion:** As a sign of acute appendicitis, MOD provides high sensitivity but limited specificity. Given that faecal impaction of the appendix frequently increases the MOD, it is often misdiagnosed as acute appendicitis.
Keywords: Acute appendicitis, Ultrasound, Feacal impaction and MOD

Background
Faecal impaction increases the outer transverse diameter of the normal appendix, frequently leading to a misdiagnosis of acute appendicitis. Recognition of preservation of the normal layering of the appendiceal wall, smaller maximal outer diameter, thinner maximal mural thickness, the absence of periappendiceal mesenteric infiltration and no demonstrably increased blood flow in the appendiceal wall should help to prevent unnecessary surgery[١], the use of ultrasonography in the diagnosis of appendicitis has been the subject of considerable study. Several sonographic criteria may be suggestive of acute appendicitis, including outer appendiceal diameter, appendiceal compressibility, echogenic inflamematory periappendiceal fat change, and increased blood flow in the appendiceal wall. The maximal outer diameter (MOD) is one of the most important morphological criteria used to differentiate between a normal and an abnormal appendix[٢–٦]. However, MOD measurement is subject to inaccuracies because non-compressible, non-inflammatory material in the lumen, such as faecal material, transudate or air, can cause the measurement to exceed upper limits of normality[٦–٨]. A MOD >٦ mm is suggestive of acute appendicitis, with a sensitivity of ١٠٠٪, a specificity of ٦٨٪, positive and negative predictive values of ٦٣٪ and ١٠٠٪, respectively, and an accuracy of ٧٩٪[٣].

Methods and materials
Study population:
From ٢٠٠٧ to July ٢٠١٢, ٥٠ consecutive paediatric patients (٣٥ boys, ١٥ girls; range ٣–١٦ years) with suspected appendicitis underwent prospective evaluation, including laboratory testing (white blood cell (WBC) count and C-reactive protein (CRP) assay) and ultrasonography on the right side of the abdomen. All patients were selected by the senior physician in the emergency department, and those enrolled in the study received a differential diagnosis of appendicitis.

Ultrasonography technique: All patients were evaluated by the same radiologist using ultrasonography. The abdomen of each patient was evaluated with an ultrasonographic machine (HDI ٥٠٠٠; Advanced Technology

Laboratories-Philips Medical Systems) and a broadband convex array transducer (٢–٥MHz). Each evaluation was supplemented with ultrasonographic assessment of the appendix and surrounding regions with a broadband linear array transducer (٥–١٢MHz) and the graded-compression technique, as previously described[١]. Colour Doppler ultrasonography was performed after greyscale ultrasonography to detect slow blood flow.

Interpretation: Our prospective real-time ultrasonographic assessment used the following criteria to differentiate between faecal impaction of the appendix and acute appendicitis: MOD, maximal mural thickness (MMT), preservation of normal appendiceal wall layering, presence of periappendiceal fat infiltration, and increase in blood flow in the appendiceal wall on colour Doppler study[٩,١٠].

A faecal-impacted appendix was defined as an appendix containing a non compressible echogenic mass without posterior shadowing within the lumen. The MOD was defined as the outer-wall to outer-wall diameter at the widest point of the appendix during transducer compression. The MMT was defined as the maximum distance from the hyperechoic luminal interface (i.e. collapsed mucosal surface) to the outer hyperechoic line (i.e. serosa and subserosal fat).

Preservation of normal appendiceal wall layering was defined according to visualization of five concentric, alternately echogenic, and hypoechoic layers radiating outwards from the lumen. The first layer corresponded to the superficial mucosal interface; the second, to the deep mucosa, including the muscularis mucosa; the third, to the submucosa and the muscularis propria interface; the fourth, to the muscularis propria; and the fifth, to the marginal interface to the serosa[١١]. The presence of peri-appendiceal fat infiltration was defined as the presence of an area of regionally increased echogenicity (hyperechoic halo) adjacent to, or surrounding, the distal ileal wall, caecum or appendix.

Increases in blood flow in the appendiceal wall were determined by increasing the colour gain until clutter was observed and then reducing the colour gain by an amount sufficient to remove the clutter from the image of the appendix. Laboratory testing comprised a WBC count, which was considered positive at .١٠٦١٠٣ mL, and a CRP assay, which was considered positive at values ٠.٥ mg dL. The surgeon was informed of the findings from the laboratory tests and ultrasonography scans before making a decision on whether to operate.

Follow-up procedures: The findings from the laboratory tests and ultrasonography scans were compared with those from pathological studies in which laparotomy was performed and used to confirm faecal impaction of the appendix without evidence of inflammation. No patients were lost to follow-up.

Statistical analysis:
For comparison of the MOD and MMT of the normal faecal-impacted appendix and acute appendicitis, the Wilcoxon rank sum test was applied. p-values less than ٠.٠٠١ were considered to indicate statistically significant difference.

Results

Of the ٥٠ patients who were clinically suspected of having appendicitis, ١٦(٣١.٩٪) had acute appendicitis, ١٥(٣٠٪) had acute gastroenteritis, ٨(١٣٪) had mesenteric lymphadenitis, ٣(٥.٠٪) had acute colitis, and ٧(١٢.٥٪) had faecal impaction of the appendix without inflammation.

Diagnoses of faecal impaction were confirmed by surgery and histological evaluations in ٣ patients with strongly suspected acute appendicitis, and by clinical and ultrasonographical studies in the remaining ٥ patients. The pathological diagnosis of the ٣ patients who underwent surgery was lymphoid hyperplasia with faecal impaction. The mucosal layer was intact without inflammatory cell infiltration (Fig ١).

Ultrasonography findings: In all cases of faecal impaction, the faecal material within the appendiceal lumen was characterized as a heterogeneous, hyperechoic mass with-out posterior shadowing (Figs ٢–٤, ٥a). In ٣ cases, the faecal material was confined to the distal segment; in ٢ cases, the faecal material spanned the entire length of the lumen; and, in ١ cases, the faecal material was absent from the middle and distal lumen segments.

The mean diameter of the faecal-impacted appendices was ٠.٦٨ cm (range, ٠.٥٤–١.٠٣ cm). The normal appendiceal wall layers were well delineated in ٦ cases (Figs ٢–٤, ٥a) and focally blurred in ١ case, which was pathologically confirmed to have normal appendiceal wall layers without inflammatory cell infiltration.

The mean MMT of faecal-impacted appendices was ٠.١٥ cm (range, ٠.٠٨–٠.٢٤ cm). Each case had a mural thickness, ٠.٣cm, which is considered normal for children aged ٦ years or younger[١٢]. ٥ cases (٧٠٪) had a mural thickness, ٢ mm. Peri-appendiceal fat infiltration was not observed in every case; in one individual, a small amount of free fluid was observed in the pericaecal area (Fig. ٣a). Increased blood flow in the appendiceal wall was not observed in every case (Fig. ٣b).

In the cases of acute appendicitis, the mean MOD was ٠.٩٧ cm (range, ٠.٦٧–٢.١٢ cm), and the mean MMT was ٠.٢٨ cm (range, ٠.١٢–٠.٤٦ cm). ١ cases (٢.٠٪) had a MOD, ٠.٢ cm, whereas ٧ cases (٣٩٪) had a MOD ٠.٣ cm. Peri-appendiceal fat infiltration was observed in ١٥ cases (٩٠٪) (Fig. ٥b).
Increased blood flow in the thickened appendiceal wall was observed in ٨ cases (٥٠٪).

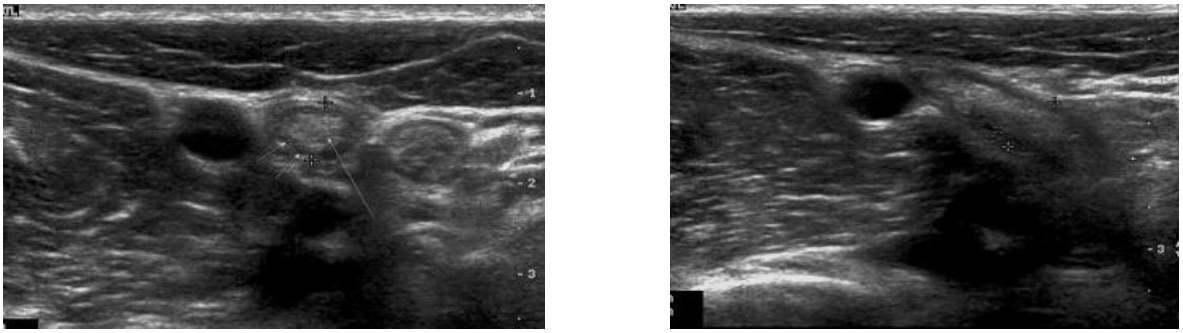

Fig ١. Pathologically confirmed faecal-impacted normal appendix. (a) Longitudinal and (b) transverse sonograms of the appendix show a distended lumen containing heterogeneous echogenic material implying faecal material (long arrow in b). Preservation of the inner hypoechoic mucosal lining (short arrows in b) is also noted.

Laboratory findings
In ٤ cases, the WBC count was high. In ١١ cases, the CRP level was high.

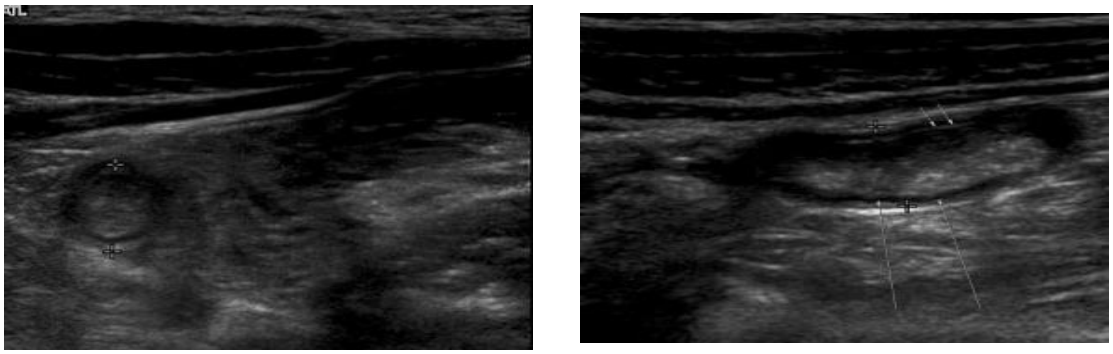

Figure ٢. A ١٠-year-old-boy with primary mesenteric lymphadenitis.
(a, b) A normal hypoechoic mucosal layer (long arrows in a) and echogenic lumen–mucosa interface (short arrows in a) are well delineated without disruption. (b) The outer transverse diameter of the appendix is approximately ٨.٢ mm. No evidence of peri-appendiceal infiltration is seen. Pathology confirmed lymphoid hyperplasia with faecal impaction.

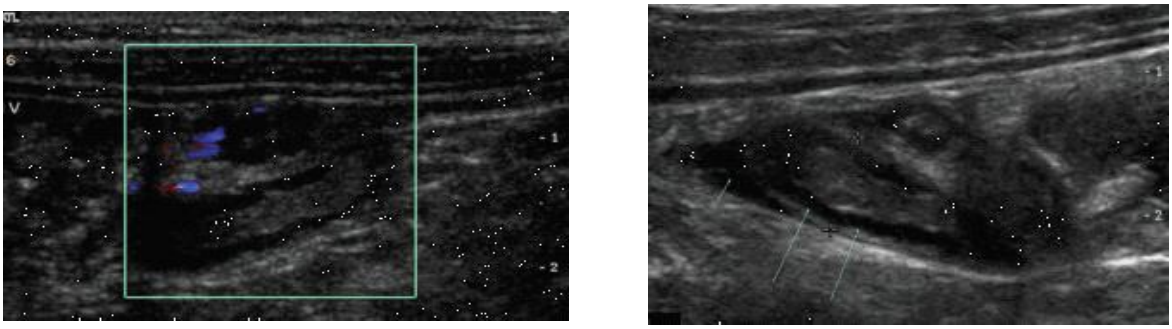

Figure ٣. A ٤-year-old boy presenting with acute gastroenteritis and mesenteric lymphadenopathy. (a) Heterogeneous faecal material is noted in the appendix. The outer transverse diameter of the appendix is ٦.٧ mm. The normal wall layers of the appendix are preserved, including a thick hypoechoic mucosal layer (long arrows); no peri-appendiceal fat infiltration is seen, but scanty free fluid is seen in the peri-appendiceal area (short arrow). (b)Another ٥-year-old boy with a faecal-impacted appendix; no demonstrably increased blood flow in the appendiceal wall is seen on colour Doppler study.

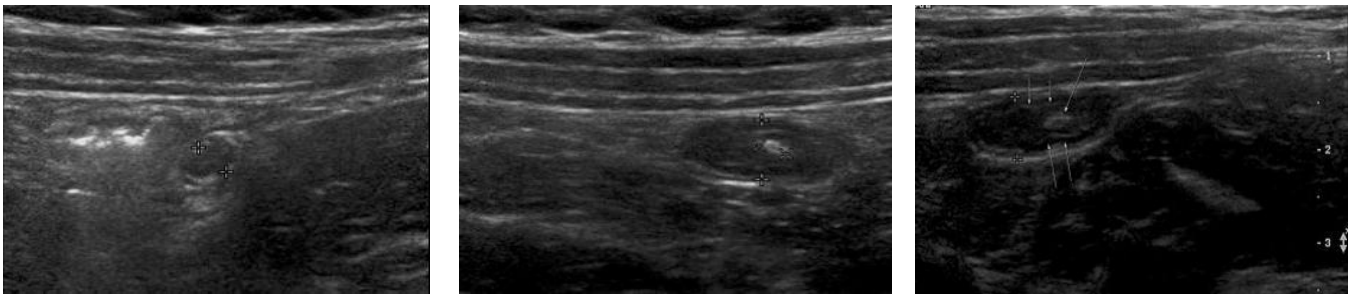

Figure ٤. A ٩-year-old boy with mesenteric lymphadenitis (follow-up study). (a) A normal appendix without faecal impaction (initial examination). (b) Follow-up ١٨ days after the initial examination. Faecal impaction with a small echogenic faecolith (longest arrow) is seen. The normal echogenic mucosa–lumen interface (short arrows) and hypoechoic mucosal layer (long arrows) are preserved. The outer transverse diameter of the appendix is ٦.٧ mm. (c) Follow-up ١٩ days after the initial examination. Faecal impaction with a small echogenic faecolith is also noted. The outer transverse diameter of the appendix is ٦.٥ mm.

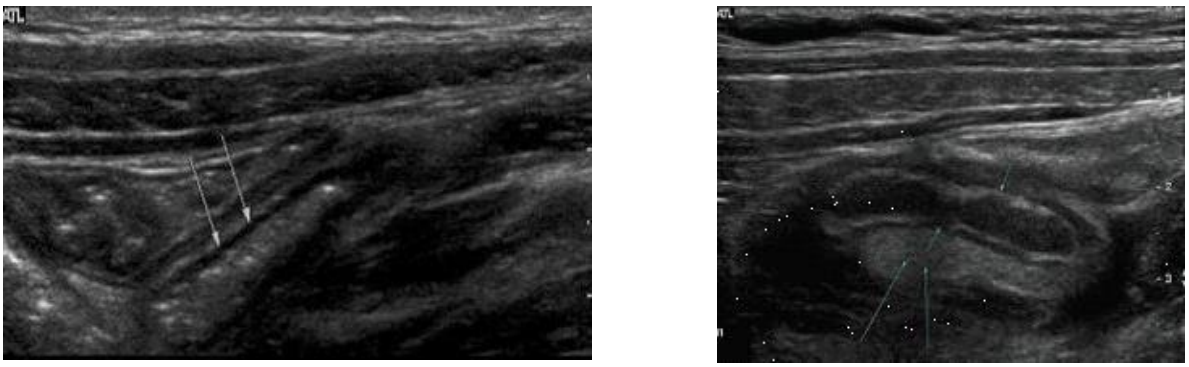

Figure ٥. Comparison between (a) faecal-impacted appendix and (b) acute appendicitis. Longitudinal ultrasonography image shows the heterogeneous echogenic feacal material impacted in the appendix and well-delineated hypoechoic inner mucosal layer (arrows).
Longitudinal ultrasonography image shows the inner hypochoic mucosal layer, which is indistinguishable from hypoechoic intraluminal pus. A focally disrupted echogenic submucosal layer (short arrows) and echogenic inflamed peri-appendiceal fat infiltration (long arrows) are also noted.

Discussion

To the best of our knowledge, the present study was the first to establish diagnostic criteria to differentiate faecal impaction of the appendix from acute appendicitis. In the clinical setting, signs of faecal impaction, including a distended appendix and tenderness, are often misdiagnosed as acute appendicitis.

Rioux[٧] described six cases in which appendices with a very thin wall, compressibility and a transverse diameter ٠.٦mm owing to faeces-induced luminal dilatation were considered as normal. Had other established criteria been employed, these appendices may instead have been considered abnormal because of their overall diameter.

In ١٩٩٧, Hahn et al.,[٦] reported a marked overlap in the diameters of normal and acutely inflamed appendices of children following ultrasonography. A diameter >٦ mm was observed in ٢٦ of ٤٥ cases (٨٠٪) with histologically proven normal appendices and lymphatic hyperplasia. The authors concluded that high diagnostic accuracy in children may be achieved only by evaluating several ultrasonographic criteria simultaneously, including the outer appendiceal diameter, appendiceal compressibility, location of the point of tenderness, presence of hyperechoic periappendiceal inflamed fatty tissue, appendiceal shape, appendicoliths, gas in the appendiceal lumen, and blood flow in the appendiceal wall[٥,٦].

The sensitivity of ultrasonography in the detection of appendicitis has been reported to be ٨٠٪–٩٧٪[٢]. An outer appendiceal diameter >٦ mm is suggestive of acute appendicitis with a sensitivity of ١٠٠٪, a specificity of ٧٠٪, positive and negative predictive values of ٦٧٪ and ١٠٠٪, respectively, and an accuracy of ٨٠٪[٣]. Therefore, as a sign of acute appendicitis, an outer appendiceal diameter >٦ mm provides high sensitivity but limited specificity.

The MOD is defined as the outer-wall to outer-wall diameter at the widest point of the appendix during transducer compression, and is calculated as the sum of both the mural thickness and luminal thickness readings at that point. Such an approach avoids any discrepancies that might result from attempting to identify the mucosal surface within the appendix, and allows for the inclusion of any non-compressible material secondary to acute appendicitis, such as pus in empyema.

However, this determination implies that any non-compressible material or non-inflammatory content, such as inspissated faeces[٧,٨] or mucoid (in patients with cystic fibrosis), will have a serious effect on the MOD. As a result, there is the potential for false-positive findings with MOD measurements. In particular, inspissated faecal material may easily result in a diameter that grossly exceeds any adopted upper limit of normality at the point of measurement [٧,٨]. Importantly, non-shadowing faecal material is not equivalent to loose faeces, which may be easily compressed out of a normal patent lumen and are often associated with fluid that facilitates their removal, or to the classic shadowing appendicolith, the presence of which strongly suggests appendicitis, regardless of the MOD[٢,١٢–١٦]. Logically, non-compressible materials have the same devastating effect on the depiction of appendiceal compressibility as they do on MOD specificity.

The inaccuracy of the MOD measurement was confirmed in recent studies by Rettenbacher et al.,[١٧] and Lowe et al.,[١٨]. Rettenbacher et al.,[١٧] measured a MOD >٧ mm in ٢١ out of ٢٤٠ control subjects (٩٪). On the basis of their overall data, the authors concluded that the ٦ mm MOD criterion is more useful for excluding, rather than confirming, acute appendicitis. However, no relevant explanation was provided for the reported grossly abnormal values in some of the normal appendices (up to ١٣mm), although endoluminal inspissated faeces could be a probable explanation. Lowe et al.,[١٨] visualized six appendices with MODs ranging from ٦.٢ mm to ٨.٠ mm that were false-positive for appendicitis.

As in the study by Rettenbacher et al.,[١٧] no morphological explanation for these false-positive findings was provided. Because of MOD measurement limitations, MMT may serve as a useful adjunctive measurement, especially for the examination of patients in whom presumed noninflammatory endoluminal material has been visualized.

The literature cites MMT limits of .٢ mm and .٣ mm as positive for appendicitis[٧,٨,١٣,١٩]. The latter limit is used more commonly because of its considerably higher specificity; however, it still lacks ١٠٠٪ sensitivity. In our cases of faecal impacted appendices, the mural thickness was ٣ mm in all cases.

Another typical sign of acute appendicitis is the absence of the hyperechoic superficial mucosal inter-face and the presence of hypoechoic deep mucosa, including muscularis mucosa, on transverse sonography. In addition, the focal or circumferential loss of the inner layer of echoes is usually suggestive of gangrenous inflammation and ulceration of the submucosa[٧]. However, in the present study, faecalimpacted normal appendices showed preservation of all layers of the appendiceal wall, except in one case that was pathologically confirmed as an intact appendiceal wall without inflammatory cell infiltration.

According to the literature, the most accurate sign of appendicitis is the presence of inflammatory fat changes, with a negative predictive value of ٩٠٪ and a positive predictive value of ٧٤٪. Although blood flow in the appendiceal wall on colour Doppler ultrasonography is also a useful indicator, sensitivity is limited to ٥٤٪[٢٠]. The value of laboratory testing in establishing a diagnosis of appendicitis has been studied extensively.

An increase in the WBC count has been shown to be an early marker of appendiceal inflammation, whereas an elevated CRP level has been shown to occur when symptoms are present for more than ١٢h or after appendiceal perforation. Previous studies have demonstrated that laboratory evaluations can exclude appendicitis when both the WBC count and CPR level are normal[٢١,٢٢]. A study by Gro¨nroos and Gro¨nroos[٢٣] demonstrated a predictive value of ١٠٠٪ for a normal WBC count and CRP level in excluding appendicitis; however, the authors did not confirm their findings in apopulation consisting exclusively of children[٢٤].

The cohort in the present study consisted of children younger than ١٦ years. A normal WBC count was observed in all ١٧ examined cases; however, an elevated CRP level was observed in ٦ out of ١١(٥٥٪) examined cases. The present study had several limitations. All MOD and MMT limits of normality were derived from were referred for ultrasonography because of acute right lower quadrant pain. There are several ways to introduce potential inaccuracies into the MOD measurement.

Although some studies have suggested that normal appendices are described on ultrasonography more often than has been reported[٥,٧,٨,١٠], the descriptions of encountered normal appendices in these studies are limited to the statements of ‘‘not meeting the selected criterion of pathology’’ employed in the studies.

Unfortunately, there is no reliable way to confirm whether all of the clinically normal appendices (i.e. those not addressed surgically) visualized in symptomatic patients would still be considered normal after post-surgical histopathological analysis. Some of these cases may actually represent unrecognized self-limiting acute appendicitis. Although disputed in the past, the concept of spontaneously resolving appendicitis is currently supported by the literature[٢,٦–٨,١٠,١٨,٢٥,٢٦].

Furthermore, in symptomatic patients, the presence of small acute and/or residual appendiceal inflammatory wall changes is always possible, even when acute appendicitis is not present during the time of examination.

The presumed mechanism of such appendiceal wall thickening (in itself not related to acute appendicitis) is sympathetic mural oedema, which is a manifestation of secondary reactive changes that develop in the vicinity of the original problem, such as acute colitis or mesenteric lymphadenitis[١٠,١٤].

In conclusion, faecal impaction of the appendix can increase the MOD, which in turn may lead to a misdialgnosis of acute appendicitis. However, preservation of the normal appendiceal wall layers, smaller MOD, thinner mural thickness, absence of demonstrable periappendiceal fat changes, and no blood flow increase in the appendiceal wall on colour Doppler US could aid in the accurate diagnosis of faecal impaction and the avoidance of unnecessary surgery.

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