

BRIEF ARTICLES

Diagnostic value of maximal-outer-diameter and maximal-mural-thickness in use of ultrasound for acute appendicitis in children

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MOD differed significantly between the two groups (0.37 cm vs 0.76 cm, $P < 0.0001$), and the median MMT also differed (0.15 cm vs 0.33 cm, $P < 0.0001$). The optimal cut-off value of the MOD and the MMT for diagnosis of acute appendicitis in children was > 0.57 cm (sensitivity 95.4%, specificity 93.4%) and > 0.22 cm (sensitivity 90.7%, specificity 79.3%), respectively.

CONCLUSION: The MOD and the MMT are reliable criteria to diagnose acute appendicitis in children. An MOD > 0.57 cm and an MMT > 0.22 cm are the optimal criteria.

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Abstract

AIM: To evaluate the maximal-outer-diameter (MOD) and the maximal-mural-thickness (MMT) of the appendix in children with acute appendicitis and to determine their optimal cut-off values to diagnose acute appendicitis.

METHODS: In total, 164 appendixes from 160 children between 1 and 17 years old (84 males, 76 females; mean age, 7.38 years) were examined by high-resolution abdominal ultrasound for acute abdominal pain and the suspicion of acute appendicitis. We measured the MOD and the MMT at the thickest point of the appendix. Patients were categorized into two groups according to their medical records: patients who had surgery (surgical appendix group) and patients who did not have surgery (non-surgical appendix group). Data were analyzed by MedCalc v.9.3. The rank sum test (Mann-Whitney test) was used to evaluate the difference in the MOD and the MMT between the two groups. ROC curve analysis was used to determine the optimal cut-off value of the MOD and the MMT on diagnosis of acute appendicitis.

RESULTS: There were 121 appendixes (73.8%) in the non-surgical appendix group and 43 appendixes (26.2%) in the surgical appendix group. The median

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INTRODUCTION

Since Puylaert^[1] described the role of ultrasound (US) as a diagnostic method for acute appendicitis in 1986, the diagnosis of acute appendicitis has become more dependent on the use of US, especially in the doubtful cases for the clinicians. Because of the smaller trunks and thinner subcutaneous fat layer in children compared to adults, US evaluation of the appendix is easier in children. According to previous reports^[1-4], radiologists have used several US findings to diagnose acute appendicitis. Among these findings, the maximal outer diameter (MOD) of the appendix was regarded as the most reliable measurement. When the MOD is > 0.6 cm, radiologists suggest the presence of acute appendicitis is indicated.

However, the MOD may be larger than 0.6 cm without acute inflammation. The concern is that the

MOD may be exaggerated by the presence of intra-luminal materials such as gas, feces and fluid^[5-7]. To decrease the false positive rate of the MOD criterion, some radiologists have recently attempted to determine another size criterion, the maximal mural thickness (MMT) of the appendix^[8-10].

The purpose of this study was to evaluate the diagnostic value of the MOD and the MMT measurements of the appendix in children with clinical suspicion of acute appendicitis and to determine the optimal cut-off values of these measurements in diagnosis of acute appendicitis.

MATERIALS AND METHODS

Among the abdominal US of the children who visited our institute for acute abdominal pain and the suspicion of acute appendicitis between July 2004 and November 2008, we selected 160 children who had a visible appendix on US. These children were aged 1-17 years (84 males, 76 females; mean age, 7.38 years).

After receiving informed consent, the children were examined by experienced radiologists with three different US units (iU22, Philips Medical Systems, Andover, MA, USA; HDI 5000 SonoCT, Philips Medical Systems, Best, The Netherlands; ATL HDI 5000, Philips Medical Systems, Andover, MA, USA). The appendix was scanned from the base to the tip under graded compression using a high resolution transducer (9-12 MHz linear transducer or a 5-8 MHz sector transducer). Then the MOD and the MMT were measured at the thickest point in the cross-sectional image (Figure 1). The MOD was defined as the distance between the outer hyperechoic borders of the the appendix, and the MMT was defined as the distance from the hyperechoic luminal interface to the outer hyperechoic border. Intra-luminal contents including fluid, gas, feces, stones or nothing were recorded.

The medical records of the patients were traced till the symptoms were resolved. We categorized the patients into two groups: patients who had surgery (surgical appendix group) and patients who recovered without surgery (non-surgical appendix group). Data were analyzed by MedCalc v.9.3 software (MedCalc, Mariakerke, Belgium). We used the rank sum test (Mann-Whitney test) to evaluate the difference in the MOD and the MMT between the two groups and used ROC curve analysis to determine the optimal cut-off values of the MOD and the MMT for diagnosing acute appendicitis.

RESULTS

The MOD and the MMT of 164 appendixes in 160 children were included in this study. Forty-four children underwent an appendectomy. The pathological diagnoses were 15 cases of acute appendicitis (without any comment), six cases of acute early appendicitis, 13 cases of acute suppurative appendicitis, six cases of acute gangrenous appendicitis, two cases of acute gangrenous appendicitis with perforation, one case of acute necrotizing appendicitis and one case of congestion. As congestion did not contain any inflammatory cells, the case of congestion was re-classified in the non-surgical

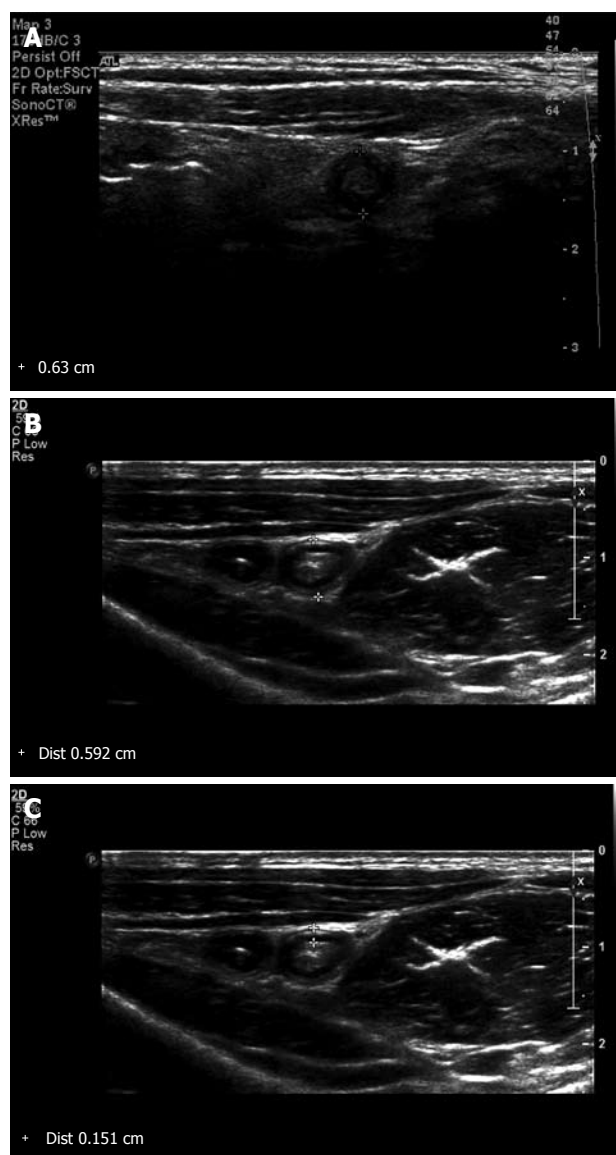


Figure 1 Measurement of MOD and MMT of an appendix in the cross-sectional image. The MOD (A) of the appendix of a 10-year-old boy who had surgery for acute appendicitis. The MOD (B) and the MMT (C) of the appendix of a 7-year-old boy who had a normal appendix in spite of acute abdominal pain.

appendix group. The case of congestion was finally diagnosed with Crohn's disease in the ileum and cecum. As a result, there were 121 appendixes (73.8%) in the non-surgical appendix group and 43 appendixes (26.2%) in the surgical appendix group.

Because each reference interval of the MOD and the MMT rejected normality ($P < 0.0001$ in each case), the Mann-Whitney test was used for the statistical analysis.

The range of the MOD was 0.20-1.45 cm in all patients, 0.20-0.69 cm in the non-surgical appendix group and 0.42-1.45 cm in the surgical appendix group. The median MOD of 0.37 cm (95% CI: 0.29-0.45 cm) in the non-surgical appendix group was significantly different ($P < 0.0001$) from the median MOD of 0.76 cm (95% CI: 0.69-0.90 cm) in the surgical appendix group. The data comparison graphs between the two groups were presented in Figure 2A.

The range of the MMT was 0.08-0.58 cm in all patients, 0.08-0.49 cm in the non-surgical appendix group

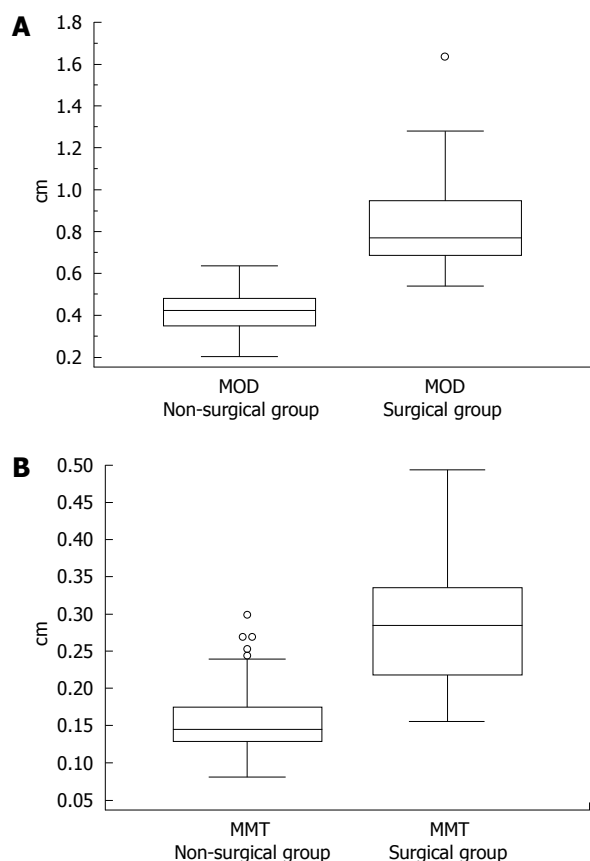


Figure 2 Data comparison graphs of MOD (A) and MMT (B) in box-and-whisker plots. The median MOD and the median MMT were significantly different ($P < 0.0001$) between two groups.

and 0.10-0.58 cm in the surgical appendix group. The median MMT of 0.15 cm (95% CI: 0.13-0.17 cm) in the non-surgical appendix group was significantly different ($P < 0.0001$) from the median MMT of 0.33 cm (95% CI: 0.30-0.38 cm) in the surgical appendix group. The data comparison graphs between the two groups were presented in Figure 2B.

By ROC curve analysis, the optimal cut-off MOD was 0.57 cm with 89.6% sensitivity, 93.2% specificity and a 13.1 positive likelihood ratio (Figure 3A). The optimal cut-off MMT was 0.22 cm with 84.6% sensitivity, 95.8% specificity and a 20.1 positive likelihood ratio (Figure 3B).

DISCUSSION

According to previous reports^[1-4,11], the diagnosis of acute appendicitis by US is based on the following findings; the MOD of the appendix > 0.6 cm; the appendix cannot be compressed with manual pressure by the examiner; the cross-sectional shape of the appendix is round rather than oval; there is an absence of gas in the appendiceal lumen; and there is hyperperfusion of the appendiceal wall on a Doppler study. However, the most credible criterion, the MOD, may be exaggerated and inaccurate in certain conditions (Figure 4)^[5-7].

Earlier, Park *et al*^[10] suggested that the MMT may have a role as a useful adjunctive measurement, especially for patients with fecal-impacted, non-inflammatory appendixes. As well as this study, there have been

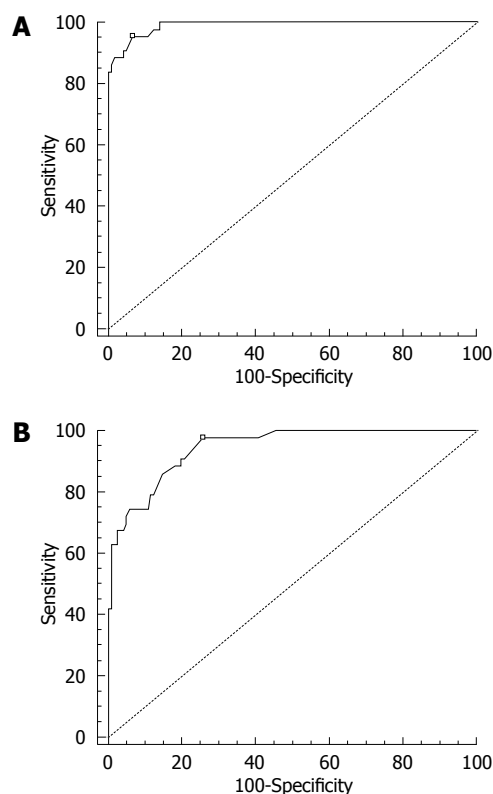


Figure 3 ROC curves of MOD (A) and MMT (B). The optimal cut-off points are marked as white square boxes on the graphs.

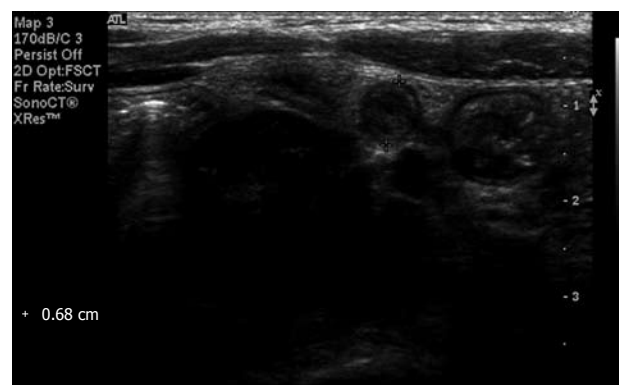


Figure 4 Cross-sectional image of a distended normal appendix in a 7-year-old boy. The MOD of the appendix was 0.65 cm. The intra-luminal hyperechogenicity was due to gas and fecal materials. We diagnosed this as normal appendix, and the symptoms spontaneously resolved.

several research studies measuring the MMT in children. Simonovsky^[8] reported that the difference in the normal appendiceal MMT between a group of young children and adolescents and an adult group was marginally significant ($P = 0.042$). In addition, the investigator stated that an MMT < 3 mm should be regarded as normal in children aged six years or younger. Wiersma *et al*^[9] also reported the sizes of the MOD and the MMT of a normal appendix in children as 0.21-0.64 cm and 0.11-0.27 cm, respectively. However, they studied only normal appendixes.

In our study, we examined data for both diseased and disease-free appendixes on a large scale, and we compared the MOD and MMT between the surgical appendix and the non-surgical appendix. In a statistical

analysis, both the MMT and the MOD had diagnostic value for acute appendicitis in children.

In addition, we were able to obtain the optimal cut-off MOD and MMT values for diagnosing acute appendicitis in pediatric patients. By ROC curve analysis, the optimal cut-off MOD was 0.57 cm with 89.6% sensitivity, 93.2% specificity and a 13.1 positive likelihood ratio. The optimal cut-off MMT was 0.22 cm with 84.6% sensitivity, 95.8% specificity and a 20.1 positive likelihood ratio. Considering that literature during the last three years has reported that the sensitivity and the specificity for diagnosis of acute appendicitis with US were 80%-100% and 86.5%-100%^[10,12-19], our study showed acceptable sensitivity and specificity. While we expected that the MMT would be more sensitive than the MOD, the MMT was less sensitive but more specific than the MOD. We presumed that the MMT could only decrease the false positive ratio of the MOD and could not affect the false negative ratio as the MOD was more sensitive. Therefore, in children, an MOD > 0.57 cm suggests the presence of acute appendicitis and an MMT > 0.22 cm enhances the possibility of having acute appendicitis.

There were several limitations to this study. At first, because our data were obtained only from visible appendixes on US, cases of perforated appendicitis were excluded. Secondly, we categorized patients according to the results of surgery, and therefore cases of chronic or abortive appendicitis may be categorized in the non-surgical appendix group. Thirdly, because the examiner was not one radiologist, inter-observer variance still exists.

In conclusion, the MOD and the MMT are reliable criteria for diagnosis of acute appendicitis in children. An MOD > 0.57 cm and an MMT > 0.22 cm are the optimal criteria.

COMMENTS

Background

US became a reliable modality for diagnosing acute appendicitis, especially in doubtful cases for clinicians. When the maximal outer diameter (MOD) of the appendix is larger than 0.6 cm, radiologists suggest the presence of acute appendicitis. However, because the MOD may be larger than 0.6 cm without acute inflammation, the maximal mural thickness (MMT) of the appendix has been evaluated as another size criterion.

Research frontiers

Dr. Wiersma and colleagues in Juliana Children's hospital in The Netherlands reported the sizes of the MOD and the MMT in the normal appendix. Dr. Park and colleagues in Kwandong University Myongji Hospital in South Korea suggested that the MMT may play a role as a useful measurement for the fecal-impacted, non-inflammatory appendix. However, they included only normal appendixes. The authors examined data from both diseased and disease-free appendixes on a large scale to evaluate the MMT and the MOD and to determine the optimal cut-off values of these measurements in the diagnosis of acute appendicitis in children.

Applications

The MOD and the MMT are reliable criteria for diagnosing acute appendicitis in children. An MOD > 0.57 cm and an MMT > 0.22 cm are the optimal criteria.

Peer review

The authors demonstrated the usefulness of measurements of MOD and MMT

in diagnosing pediatric acute appendicitis. They compared the MOD and MMT between surgical and non-surgical appendix groups and showed significant differences between the two groups. They also determined optimal cut-off value of MOD and MMT for diagnosis of acute appendicitis. The manuscript was well organized and well written.

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