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Ultrasonography for the Diagnosis of Acute Appendicitis

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Acute appendicitis is usually encountered clinically as acute abdomen. Typical cases are easy to diagnose, but it can sometimes be very difficult to make a diagnosis in atypical cases. We retrospectively studied patients who underwent ultrasonography for right-sided lower abdominal pain suggesting acute appendicitis, and assessed the accuracy of ultrasonic diagnosis. The subjects were 202 patients (100 males and 102 females) aged 6-89 years (mean: 33.3 years). From the ultrasonic findings, appendicitis was classified as follows: 1) catarrhal: a clear layer structure of the appendiceal wall and mucosal edema; 2) phlegmonous: an ill-defined layer structure of the appendiceal wall, moderate enlargement of the apendix, and maximum transverse dimension of ≧10 mm; and 3) gangrenous: unidentifiable layer structure of the appendiceal wall and marked enlargement to form a mass. The appendix was visualized in 142 of the 202 patients (70.3 %). When the appendix was detected, the sensitivity, specificity and accuracy of ultrasound for making a diagnosis of appendicitis were 97.6 %, 82.0 %, 91.5 %, respectively.

With regard to assessment of the severity of inflammation, ultrasonic and histologic findings were concordant in 61.2 % of the patients. However, ultrasound was shown to possibly underestimate the extent of inflammation. On the other hand, 11 of the 60 patients with an undetectable appendix (18.3 %) were clinically diagnosed as having appendicitis. The pathologic diagnosis was catarrhal appendicitis in 3 patients and phlegmonous appendicitis in 8 patients. In patients with an undetectable appendix, the possibility of catarrhal or phlegmonous appendicitis should be kept in mind.

Key words : Acute appendicitis, Ultrasonography, Acute abdomen

INTRODUCTION

Acute appendicitis is most often encountered clinically as acute abdomen. It is easy to diagnose typical cases of this disease, but we occasionally have great difficulty in diagnosing atypical cases. Recently, ultrasound has been reported to be useful for the diagnosis of appendicitis [1-9, 11-13, 15, 17-21, 23-31, 34]. In this study, we investigated the ability of ultrasonography to detect acute appendicitis by a retrospective review of patients who had undergone ultrasonography to assess right-sided lower abdominal pain suggestive of acute appendicitis.

The severity of inflammation is an important factor in deciding on the treatment of appendicitis. Many authors recommend conservative treatment for catarrhal appendicitis, while surgery is needed for phlegmonous or more advanced appendicitis [15, 19, 24, 31, 32]. The severity of inflammation is assessed on the basis of the findings on physical examination, blood tests, and ultrasonography. Among these, ultrasonographic findings are particularly important. We compared the severity of inflammation revealed by ultrasonography with the actual histological findings to determine the accuracy of the ultrasonographic diagnosis of inflammation.

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SUBJECTS AND METHODS

The subjects were 202 patients who presented to our hospital with right lower quadrant pain in the 3 years from January 1998 to December 2000 and were clinically suspected of having acute appendicitis. The subjects comprised 100 males and 102 females aged 6-89 years (mean: 33.3 years). Ultrasonography was performed by technicians from the ultrasound laboratory. The ultrasound unit was a Toshiba SSA250A. Although a 7.5 MHz probe with an annular array transducer was generally used, a 3.5 MHz convex probe was also employed depending on the patient's physique and the depth of the appendix.

Physical examination and diagnosis were performed by surgeons with 10 years or more of experience, and the therapeutic strategy was decided from the clinical course as well as the physical and laboratory findings, the ultrasonic diagnosis, and (if required) the computed tomography findings. Patients who were judged to need surgical treatment underwent operation as soon as possible, while those who were not considered candidates for surgery were hospitalized or followed up on an outpatient basis.

On the basis of ultrasonographic findings, appendicitis was classified as follows: 1) catarrhal: the appendix was tubular with a clear layer structure of the appendiceal wall, slight mucosal edema, and a maximum transverse diameter of $<$ 10 mm; 2) phlegmonous: there was an ill-defined layer structure of the appendiceal wall, moderate enlargement of the appendix, and a maximum transverse diameter of $\geqq$ 10 mm; and 3) gangrenous: there was an ill-defined or unidentifiable layer structure of the appendiceal wall and severe enlargement of the appendix to form a mass [16]. The Figure shows typical cases. Resected specimens were stained with hematoxylin-eosin and histological findings were classified as follows: 1) catarrhal: mild inflammatory cell infiltration localized to the mucosa; 2) phlegmonous: diffuse neutrophil infiltration of the whole appendiceal wall with abscess or ulcer formation; and 3) gangrenous: suppurative necrosis of all layers of the appendiceal wall.

RESULTS

Ultrasonography failed to visualize the appendix in 60 of the 202 patients (29.7 %). The appendix was detected in the other 142 patients (70.3 %), consisting of 49 with a normal appendix, 24 with catarrhal appendicitis, 53 with phlegmonous appendicitis, and 16 with gangrenous appendicitis (Table 1).

Of the 202 patients, 96 underwent surgery and the other 106 were followed up. Some patients who remained under observation were treated with antibiotics after hospitalization and fasting, but most were followed up at the outpatient clinic without antibiotic therapy. The 106 patients who did not undergo surgery all showed improvement, with no exacerbation of their symptoms, physical findings, and laboratory data throughout the follow-up period.

We assessed the diagnostic accuracy of ultrasonography for the 142 patients in whom the appendix were visualized with ultrasonography. Among them, 57 patients recovered without surgery, and they were judged as not having appendicitis. As a relult, there are 83 true positive cases, 47 true negative cases, 10 false positive cases, and 2 false negative cases. The sensitivity, specificity, accuracy, positive predictive value, negative predictive value were 97.6 %, 82.0 %, 91.5 %, 89.2 %, 95.5 %, respectively.

Assessment was also done in the 85 patients in whom surgery was performed and pathological information was obtained. Two patients were false negative on ultrasonography, so both the sensitivity and accuracy were a high 97.6 % and the positive predictive value was 100 %.

Next, the ability of ultrasonography to assess the severity of inflammation was investigated in the 96 patients who underwent surgery (for whom a pathologic diagnosis was obtained). When 11 patients with an undetectable appendix were excluded, the number remaining was 85. Ultrasonic and histologic findings were concordant in 52 of these 85 patients (61.2 %). Among the 33 cases without agreement, 27 were underestimated and 6 were overestimated by ultrasound. With regard to distinguishing catarrhal from phlegmonous inflammation, which is important when evaluating the need for surgical treatment, the severity was underestimated by ultrasound in 9 patients (histologically

phlegmonous or more advanced appendicitis was misjudged as catarrhal or a normal appendix) (Table 2).

DISCUSSION

In recent years, ultrasonography has achieved an important place in the diagnosis of acute appendicitis. A number of investigators have reported that the use of ultrasonography to detect acute appendicitis achieved a sensitivity of 75-95 %, a specificity of 95, and 85-95 % in accuracy [6].

The severity of inflammation is important when evaluating candidates for surgery to treat acute appendicitis. Since catarrhal appendicitis is reversible, conservative treatment may be adopted [15, 24, 31, 32]. On the other hand, phlegmonous and gangrenous appendicitis require surgical treatment. Igami *et al.* [7] classified the ultrasonographic features of the appendix into five patterns and noted a correlation between ultrasonographic and histologic findings.

Regarding the ultrasonic features of the normal appendix, Puylaert [20] stated that a blind-ended luminal structure should be visualized and the appendiceal wall should be clearly depicted as a triple-layered structure. In Japan, Yuasa *et al.* [34], Shimizu *et al.* [26], and Itoshima *et al.* [9] have also mentioned the layered structure of the wall. This structure is maintained in catarrhal appendicitis, while a cystic pattern with a heterogenous internal echo is seen in phlegmonous appendicitis. When the disease progresses to gangrenous appendicitis, the muscularis mucosae ruptures and the appendiceal wall is destroyed.

The maximum dimension of the appendix is also an important factor for ultrasonic evaluation. Motoyama *et al.* [15] and Takase *et al.* [28] considered that a transverse diameter ≧ 10 mm in a patient with phlegmonous or more advanced appendicitis was an indi-

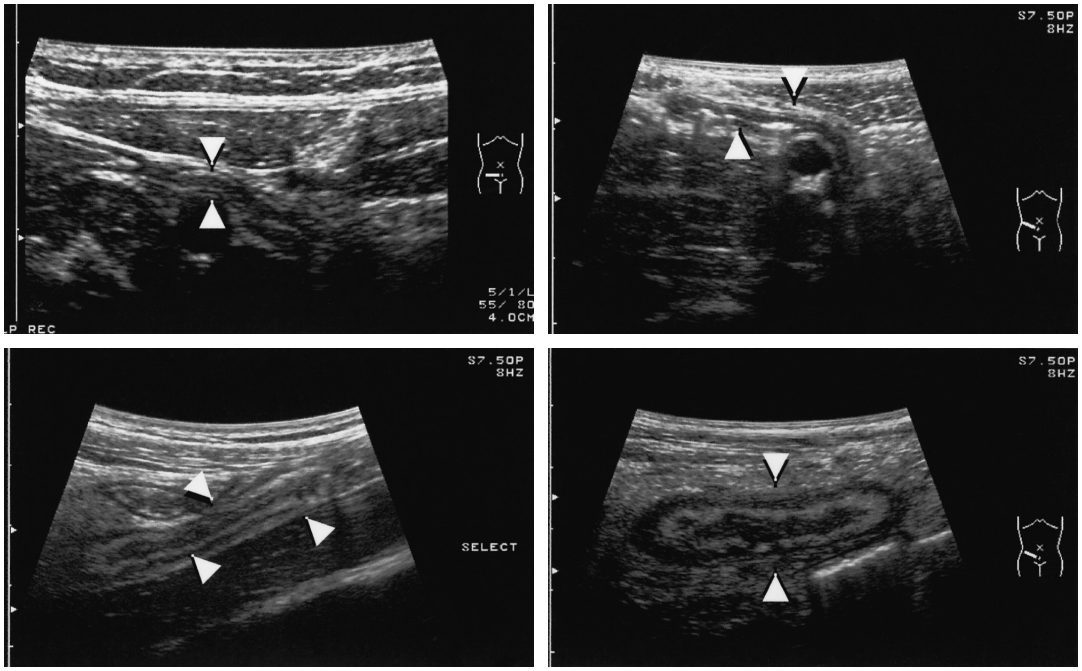

Figure legend

A	B
C	D

Typical ultrasonographic findings of the normal appendix and appendicitis
A: Normal appendix **B:** Catarrhal appendicitis
C: Phlegmonous appendicitis **D:** Gangrenous appendicitis

cation for surgical treatment. Jeffrey *et al.* [12] defined a diameter≧7 mm as indicating acute appendicitis, since the appendix measured ≧7 mm in 84 out of 86 patients with ultrasonically depicted acute appendicitis. Similarly, Schwerk *et al.* [25] and Asano *et al.* [2] considered a diameter ≧ 7 mm as an indication for surgery, while Harihara *et al.* [5] and Araki *et al.* [1] regarded a diameter ≧8 mm as requiring surgery. On the other hand, Ido *et al.* [6] considered that either a diameter ≧ 5 mm, or loss of the layer structure even with a diameter ≦ 4 mm, was an indication for surgery, and noted a sensitivity of 87.3 %, a specificity of 98.5 %, and an accuracy of 96.7 % for these parameters. However, this resulted in unnecessary appendectomy in 14 % of patients with catarrhal appendicitis and an intact appendix (17 out of 119 surgical patients).

Other ultrasonographic findings include the absence of peristalsis, lack of compressibility, presence or absence of a fecalith, and thickened bowel wall in the ileocecal region. Wada [31] stated that the appendix can be defined as intact and acute appendicitis can be ruled out only when the appendix is ≦ 6 mm in transverse diameter and the entire organ can be visualized.

The present results were obtained using the criteria described earlier, but these criteria were shown to possibly underestimate the severity of appendiceal inflammation. Although we defined phlegmonous appendicitis as existing when the maximum transverse diameter was ≧ 10 mm, the rate of agreement would be increased by using 8 mm. However, findings other than the maximum transverse diameter should also be taken into account, so the criteria for ultrasonographic diagnosis require further investigation.

With regard to examination techniques, removal of intestinal gas by slow compression using a 7.5 MHz probe is believed to facilitate depiction of the appendix [2, 21, 31]. However, the ultrasonographic diagnosis of appendicitis requires expertise, so variations in the experience and skill of the examiner are a problem.

In the present study, ultrasound failed to visualize the appendix in 60 cases (29.7 %). Of these 60 patients, 11 (18.3 %) were diagnosed clinically as having appendicitis. Possible causes of an undetectable appendix include masking by intestinal gas, the patient's physique (obesity, excessive subcutaneous fat, and an excessive abdominal wall thickness), and location of the appendix deep in the abdomen or above the cecum [2]. Recently, some authors have emphasized the usefulness of computed tomography for assessment of appendicitis [14, 22, 33] and it may be of value in cases of an ultrasonically undetectable appendix. However, the simplicity of ultrasonography and the ability to depict the layer structure of the appendiceal wall indicate that ultrasound is highly useful and should be the modality of first choice.

Ultrasonography may help in deciding the site of the skin incision at surgery. In another study, we marked the skin overlying the appendix during ultrasonography in 16 preoperative patients. As a result, in 10 patients who underwent laparotomy via a transverse abdominal skin incision, this marking was helpful for identfying the appendix although the value of the marking was not apparent in 6 patients undergoing laparotomy via a pararectus incision. From this result, preoperative marking was suggested to assist in identifying the appendix at surgery when using a transverse abdominal incision.

In conclusion, When the appendix was visualized ultrasonically, the sensitivity, specificity and accuracy of using this imaging method for the diagnosis of appendicitis were 97.6 %, 82.0 %, 91.5 %, respectively. Ultrasonographic and histologic findings regarding inflammation of the appendix were concordant in 61.2 % of patients. However, ultrasound may underestimate the severity of inflammation, so this should be taken into consideration when distinguishing catarrhal from phlegmonous appendicitis, which is important to assess the need for surgical treatment. In 11 of the 60 patients with an ultrasonically undetectable appendix (18.3 %), the clinical diagnosis was appendicitis. Histologically, 3 cases were catarrhal and 8 were phlegmonous, so none of them had a gangrenous appendix. In patients with an undetectable appendix, the possibility of catarrhal or phlegmonous appendicitis should be kept in mind.

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