Ultrasound-Based Decision Making in the Treatment of Acute Appendicitis in Children

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Background/Purpose: Imaging techniques are used widely to diagnose appendicitis. However, the negative appendectomy rate remains at about 15%. The authors assessed ultrasound-based decision making in the treatment of acute appendicitis in children.

Methods: The authors prospectively studied 165 consecutive children (3 to 15 years old) evaluated for appendicitis. Diagnosis and treatment were based solely on ultrasound scan findings. Criterion for appendicitis was a diameter exceeding 6 mm. Severity was classified into 4 grades based on the appearance of intramural appendiceal structure. Patients with grades I or II received antibiotic therapy. Patients with grades III or IV underwent appendectomy.

Results: Ultrasound scan diagnosed appendicitis in 93 children (grade I, 7; grade II, 17; grade III, 41; and grade IV, 28). All but 2 patients with grades I or II underwent antibiotic therapy without complication. All grades III or IV patients underwent appendectomy. There was no negative appendectomy among 76 appendectomies during this period. Ultrasound-based prediction of severity was correct in 67 cases (88%). Ultrasonography identified other pathology in 39.

Conclusions: Ultrasonography in children cannot only visualize all inflamed appendices but also predict severity of disease. Treatment based entirely on ultrasound scan identified patients who required surgery for severe appendicitis and permitted successful conservative treatment for mild appendicitis.

INDEX WORDS: Appendicitis, ultrasonography, outcome, severity.

APPENDECTOMY has long been established as the definitive treatment for acute appendicitis. However, negative appendectomy rates as high as 20% have been reported.[1] Despite recent advances in imaging technology, a population-based analysis in the United States found that the incidence of unnecessary appendectomy has not changed.[2] Even studies showing the diagnostic accuracy of imaging techniques have not eliminated unnecessary appendectomies.[3-11] Based on our 10-year experience using ultrasound scan to diagnose appendicitis in children, we are convinced that ultrasonography can identify inflamed appendices with 100% sensitivity and also can determine the severity as well.[12] We feel that mild appendicitis can be treated successfully by conservative means. This prospective study analyzed a consecutive series of children evaluated for appendicitis whose diagnosis and treatment were based solely on the results of ultrasonography.

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MATERIALS AND METHODS

Study Subjects

We prospectively analyzed all children (15 years or younger) suspected of having acute appendicitis with abdominal pain and tenderness, who presented to Toyohashi Municipal Hospital, a local hospital serving a population of 400 000, from June 1999 to March 2001.

Ultrasonographic Diagnosis Criteria and Severity Grading of Appendicitis

All ultrasound examinations were performed using the Logiq 400 (GE Yokogawa Medical Systems, Tokyo, Japan) with a wideband 5 to 10 MHz linear array transducer by a single surgeon using the graded compression technique.[13] A tubular structure with a cul-de-sac lacking peristalsis was searched for, and a diagnosis of appendicitis was made when the diameter of the structure was greater than 6 mm during sustained compression.[4] The severity of appendicitis was classified according to the layer patterns of the appendiceal wall as described by Yuasa in 1986.[12,14] In brief, the wall of appendix appears as 4 layers from inside to outside as follows: hypoechoic, echogenic, hypoechoic, and echogenic. The inner echogenic layer corresponds histologically to the submucosal layer. Severity was classified into 4 grades based on the appearance of the echogenic submucosal layer (Fig 1). As the intensity of the inflammation increases, the appearance of the submucosal layer is transformed according to the following series: (I) thin and smooth, (II) thick and smooth, (III) thick and irregular or thin and intermittent, to (IV) unidentifiable, with amorphous inner structures (Figs 1 and 2).[12,14] The pathologic correlation is as follows: grade I predicts early appendicitis, grade II predicts mild suppurative appendicitis, grade III predicts severe suppurative or gangrenous appendicitis, and grade IV predicts gangrenous appendicitis.[12]

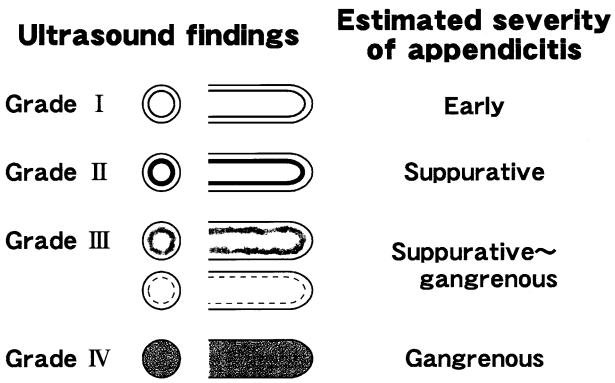

Fig 1. Ultrasound classification of appendicitis based on the appearance of the inner echogenic layer. Grade I, a thin and smooth submucosal layer predicts early appendicitis. Grade II, a thick and smooth submucosal layer predicts suppurative appendicitis. Grade III, an irregular thick or thin intermittent submucosal layer predicts suppurative or gangrenous appendicitis. Grade IV, a loss of the submucosal layer predicts gangrenous appendicitis.

Treatment Decision Tree Based on Ultrasonographic Findings

Patients with grades I or II were treated conservatively by intravenous administration of an antibiotic (flomoxef, Shionogi, Co, Osaka, Japan; 50 mg/kg to a maximum of 1 g, twice daily). The antibiotic was administered until tenderness resolved. Patients with grades III or IV underwent appendectomy. Those patients with conditions other than appendicitis were treated as appropriate. Patients without identifiable pathology were observed. No appendectomy was performed unless ultrasound scan uncovered evidence of appendicitis.

Pathologic Criteria for Determining the Severity of Appendicitis

The criteria for the histopathologic diagnosis are early appendicitis, polymorphonuclear neutrophil infiltration in the mucosa (and submucosa) with mucosal ulceration; suppurative appendicitis, transmural polymorphonuclear neutrophil infiltration; and gangrenous appendicitis, presence of gangrenous tissues, including perforation. Perforation was diagnosed macroscopically.

Clinical Diagnosis Based on Physical Examination Results

Physical findings were recorded. The clinical diagnosis was defined as definite appendicitis when both rebound tenderness and muscle guarding were present, unlikely appendicitis when neither rebound nor guarding was present, and equivocal when either rebound or guarding existed, but not both.

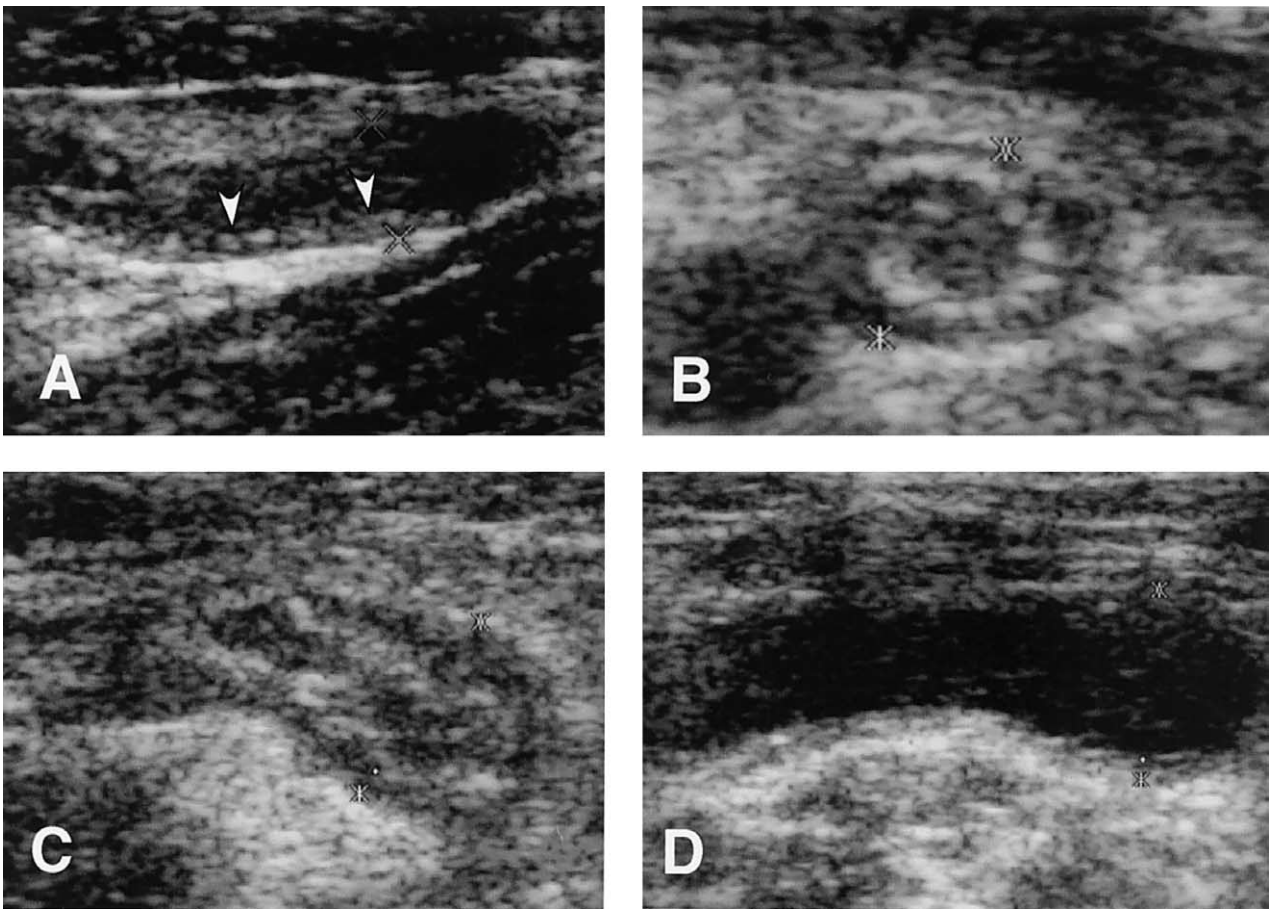

Fig 2. Representative ultrasound images for each grade of appendicitis. (A) Grade I; (B) grade II; (C) grade III; (D) grade IV. The arrowheads indicate the inner echogenic layer.

RESULTS

One hundred sixty-five children, 79 boys and 86 girls, were evaluated, and all were enrolled in this study. The mean age was 10.6 ± 3.4 years (± SD), ranging from 3 to 15 years. Four children (2.4%) were obese with body mass index more than 25 kg/m^2. A tubular structure exceeding 6 mm was visualized in 93 patients and was classified as grade I in 7 cases, grade II in 17 cases, grade III in 41 cases, and grade IV in 28 cases. Ultrasound diagnosis was made at the initial ultrasound examination in all except 4 patients who required a second examination.

Table 1. Ultrasound Grade of Appendicitis and Surgical Pathology in 76 Appendectomies

Ultrasound Grade of Appendicitis	Pathology		
	Early	Suppurative	Gangrenous
I (n = 2)	**0**	*2*	0
II (n = 5)	0	**5**	0
III (n = 41)	*2*	**13**	**26** (2)
IV (n = 28)	0	*5*	**23** (13)

NOTE. Numbers in parenthesis indicate perforation. Numbers in bold indicate correct prediction of severity, and numbers in italics indicate wrong prediction.

Grades I and II

Of the 24 patients in this group, 2 patients with grade II findings underwent laparoscopic appendectomy because the parents refused conservative treatment. Both patients had suppurative appendicitis confirmed histologically.

Twenty-two patients were treated conservatively, and symptoms resolved in all cases. The average period until resolution of tenderness was 4.2 days (range, 1 to 6 days). Ultrasound scan confirmed the disappearance of tubular structures in 14 patients, and the diameter had decreased to less than 6 mm in 5. Ultrasound was not repeated in 3 other patients. During a follow-up period averaging 36.0 months (range, 24 to 45 months), 6 patients (27.3%; grade I, 3 and II, 3) had a recrudescence of their symptoms (interval, 1, 1, 2, 5, 10, and 13 months). In 5 patients, ultrasound scan again showed a tubular structure exceeding 6 mm rated as grade I or II (grade I, 2 and II, 3). The remaining patient consulted another physician who performed an appendectomy. All 6 patients had fibrous adhesions of the appendix, establishing that appendiceal inflammation had occurred previously in addition to acute inflammation of the appendix.

Grades III and IV

All 69 patients in this group underwent appendectomy (laparoscopic, 38 and open, 31) and had appendicitis confirmed histologically. Although, at first, all appendicitis was approached laparoscopically, we adopted an open approach when the ultrasound findings suggested perforation after we experienced 2 conversions to open operations of 5 laparoscopic appendectomies for ruptured appendicitis. We experienced no conversions since then.

Diagnosis was delayed in 1 patient. The initial ultrasound diagnosis was severe enteritis, and his symptoms of abdominal pain and diarrhea subsided with antibiotics but recurred 10 days after the onset. A grade IV tubular structure was identified at that time, and the perforated appendix was removed. The patient recovered without complications. Three other patients in this group required a second ultrasound examination a few hours after the first because the initial examination was nondiagnostic.

Correlation Between the Ultrasound Grade of Appendicitis and Surgical Pathology

No normal appendices were removed in this series. Among the 76 patients who underwent appendectomy including the 5 recurrences, 67 patients (88.2%) had the severity correctly predicted by ultrasound (Table 1). Two incorrect assessments were in obese teenage boys with early appendicitis. By retrospective analysis, the thin smooth submucosal layer (grade I) was interpreted mistakenly as thin intermittent (grade III). The error occurred because the appendices were too deep for high-resolution ultrasound scan to visualize them well. Most perforated appendicitis was grade IV, and no perforation occurred in grade I or II disease.

Nonappendicitis Group

Among the 72 patients who did not have ultrasound-diagnosed appendicitis, 39 patients (54.2%) had some other pathology identified by ultrasonography. Other diagnoses included terminal ileitis in 14 patients, mesenteric lymphadenitis in 6, enteritis in 10, colitis in 2, diverticulitis in 1, intussusception in 2, left-sided superior mesenteric vein (malrotation) in 1, ovarian cyst in 2, and severe constipation in 1. The patient with intussusception underwent surgery, and the other 38 received conservative therapy with a successful outcome. The other 33 patients without identified pathology were observed and recovered uneventfully. A normal appendix was visualized in 19 (26.4%) of the 72 patients. During a follow-up of 33.4 months (range, 23 to 45 months) 2 patients with terminal ileitis had suppurative and gangrenous appendicitis after 6 and 31 months (ultrasound grade III).

Relationship Between the Ultrasonographic Diagnosis and the Clinical Diagnosis Based on Physical Examination

The 34 patients whose clinical diagnosis was definite appendicitis included 3 patients without appendicitis who had correct diagnosis by ultrasound scan. Eight of 73 patients who were felt unlikely to have appendicitis had correct diagnosis by ultrasound scan as of grade III or IV appendicitis and underwent appendectomy (Table 2).

DISCUSSION

Despite numerous studies documenting the diagnostic accuracy of ultrasonography and computed tomography in acute appendicitis, these imaging techniques have remained adjuncts in surgical decision making.[3-11] Recently, computed tomography has been reported to be superior to ultrasonography for diagnosing appendicitis in adults.[1,8,15] The use of computed tomography in children is also increasing, but its value remains uncertain.[10,11] This study shows that ultrasound scan provides absolute indications for appendectomy in children, similar to hypertrophic pyloric stenosis in infants.[16] This is the first series to be published in which no negative appendectomies were performed. Of course, we realize that the excellent results are partially because the ultrasound examination was performed by a single experienced surgeon and because there were few obese children in the Asian population, but our results may be applied to children without obesity around the world. Operator dependency of ultrasonography is another issue and is closely associated with the examiners' experience.[30] Surgeons familiar with the regional anatomy can get direct feedback during surgery and are good candidates for becoming excellent sonographers.

The relationship between the ultrasonographic appendiceal intramural layer structure and the severity of appendicitis has been noticed previously[6,17-21] but has received little attention. This study proved prospectively, for the first time, that the echogenic submucosal layer is a reliable landmark for classifying the seriousness of appendicitis. Severity was predicted correctly in 88.2% of patients who underwent appendectomy. A thick smooth echogenic layer on ultrasound scan (grade II) may represent submucosal edema and hyperemia in suppurative appendicitis, whereas an irregularly thick or intermittently thin echogenic layer (grade III) represents submucosal ulceration or necrosis in suppurative or gangrenous appendicitis. An amorphous structure (grade IV) represents destruction of the normal architecture in gangrenous appendicitis.[12]

Table 2. Correlation Between Clinical Diagnosis and Ultrasound Findings

Ultrasound Findings	Clinical Diagnosis		
	Definite (n = 34)	Equivocal (n = 58)	Unlikely (n = 73)
Appendicitis			
Grade IV (n = 28)	14* (14)	13 (13)	1 (1)
Grade III (n = 41)	16 (16)	18† (18)	7 (7)
Grade II (n = 17)	1	9 (1)	7 (1)
Grade I (n = 7)	0	3	4
Other than appendicitis			
n = 72	3	15	54

NOTE. Numbers in parenthesis indicate appendectomies.
*Including 1 case of delayed diagnosis.
†Including 2 cases of early appendicitis.

Ultrasonography also enables individualized treatment based on severity of disease. Mild appendicitis, accounting for 25.8% of cases in our series, was treated conservatively without complication. In 1995, Eriksson and Granstrom[22] prospectively administered antibiotic therapy in lieu of surgery in 20 patients with suspected appendicitis, but 1 patient had a perforation. Those who advocate conservative management for localized perforated appendicitis documented a 7% to 22% failure rate for initial antibiotic therapy.[23,24] Individualizing treatment based on objective ultrasonographic criteria produced a 100% success rate for conservative treatment. Mild appendicitis may include spontaneously resolving appendicitis, which has recently been recognized and reported to account for 8% of cases of appendicitis.[25] However, in previous studies, spontaneous resolution has been based on only clinical evaluation and not objective criteria.[4,25,26] Our ultrasound criteria of grade I and II may represent self-limiting appendicitis. Although one may criticize this conclusion as lacking pathologic confirmation of mild appendicitis in grade I and II patients, pathologic results of 2 grade II patients who underwent surgery, operative findings of recurrent cases, and our previous retrospective data[12] support the view that grade I and II patients had true appendicitis. A recurrence rate of 27% was the only limitation to conservative therapy. However, parents generally choose conservative therapy, although we recently have begun to inform them of the high recurrence rate. Our data suggest that mild appendicitis recurs as a mild case when it does recur.

This series confirmed that ultrasound scan identifies other pathology-producing symptoms in about half of the patients without appendicitis.[5,18,27,28] Terminal ileitis, mesenteric lymphadenitis, and diverticulitis of the right colon, all of which mimic appendicitis clinically, were identified easily by ultrasonography. However, as seen in our case of a delayed diagnosis, it is true that visualization of thickened intestinal walls by ultrasonography does not exclude appendicitis.[27,29] Ultrasound examination should be repeated whenever the surgeon feels any concern that appendicitis may exist.[19] This is the only

clinical decision required. Normal ultrasound examination and diagnoses other than enterocolitis excluded appendicitis in our series, unlike previous reports.[7,30] Even when ultrasound scan cannot depict appendicitis itself, periappendiceal inflammation can be always detected by ultrasonography.[14]

It is generally believed that attempts to reduce the rate of negative appendectomies will raise the perforation rate.[31] However, our series had 16.1% perforation rate (15 of 93 cases of appendicitis), which is similar to the median rate of 20% in previous surveys.[1,2] An imaging technique is considered beneficial only when the clinical diagnosis is equivocal.[1,7,30,32,33] However, immediate appendectomy for cases considered clinically unequivocal still yields a 6% to 25% negative appendectomy rate.[10,30,32,33] In this series, ultrasonography helped avoid 3 negative appendectomies in 34 clinically definite cases and detected 8 cases requiring appendectomy in 73 unlikely cases (Table 2). Thus, ultrasonography also has its place in "unequivocal cases."[30]

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