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Added Value of Structured Reporting for US of the Pediatric Appendix: Additional CT Examinations and Negative Appendectomy

소아 충수 초음파 검사에서 구조화 판독문의 부가가치: 추가 CT 검사 및 음성 충수절제술의 관점에서

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Purpose This study aimed to determine the incremental value of using a structured report (SR) for US examinations of the pediatric appendix.

Materials and Methods Between January 2009 and June 2016, 1150 pediatric patients with suspected appendicitis who underwent US examinations of the appendix were included retrospectively. In November 2012, we developed a five-point scale SR for appendix US examinations. The patients were divided into two groups according to the form of the US report: free-text or SR. The primary clinical outcomes were compared between the two groups, including the rate of CT imaging following US examinations, the negative appendectomy rate (NAR), and the appendiceal perforation rate (PR).

Results In total, 550 patients were included in the free-text group and 600 patients in the SR group. The rate of additional CT examinations decreased by 5.3% in the SR group (8.2%, $p = 0.003$), and the NAR decreased by 8.4% in the SR group (7.8%, $p = 0.028$). There was no statistical difference in the appendiceal PR (37.6% vs. 48.0%, $p = 0.078$).

Conclusion The use of an SR to evaluate US examinations for suspected pediatric appendicitis results in lower CT use and fewer negative appendectomies without an increase in appendiceal PR.

Index terms Appendicitis; Ultrasound; Appendectomy; Computed Tomography, X-Ray; Report

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INTRODUCTION

Acute appendicitis is the most frequent cause of acute abdominal surgery in pediatric patients (1). US is the preferred primary imaging modality for diagnosing acute appendicitis in children because of the lack of ionizing radiation or without the need for patient preparation (2).

US results regarding the likelihood of appendicitis have to be delivered accurately and efficiently by radiologists to referring clinicians. However, US exam reports often contain inconsistent or noncommittal language that creates uncertainty about the radiologist's impression on the likelihood of appendicitis (3). This uncertainty can cause referring clinicians to perform additional CT examinations resulting in radiation exposure and delay in the diagnosis of appendicitis or unnecessary surgery (negative appendectomy).

Standardized structured reports (SRs) have been successfully implemented in the field of radiology to improve communication between radiologists and clinicians (4, 5). Several researchers have developed SR for appendiceal US and reported improvements in diagnostic performances and clinical outcomes (3, 6-8). The previous study by Nielsen et al. (8) described a significant decrease in negative appendectomy rate (NAR) by introduction of SR, but appendiceal perforation rate (PR) was not rendered in this study. PR indirectly represents false-negative and delayed diagnoses.

Our institution has developed and implemented a SR for US exams obtained for suspected appendicitis, in which radiologists were asked to describe or check predefined US findings and conclude the likelihood of appendicitis using a five-point scale system that includes equivocal US examination results.

The purpose of this study was to determine the incremental value of using a SR for US of the pediatric appendix by comparing the CT utilization rate, NAR, and PR of the SR group with those of the free-text group.

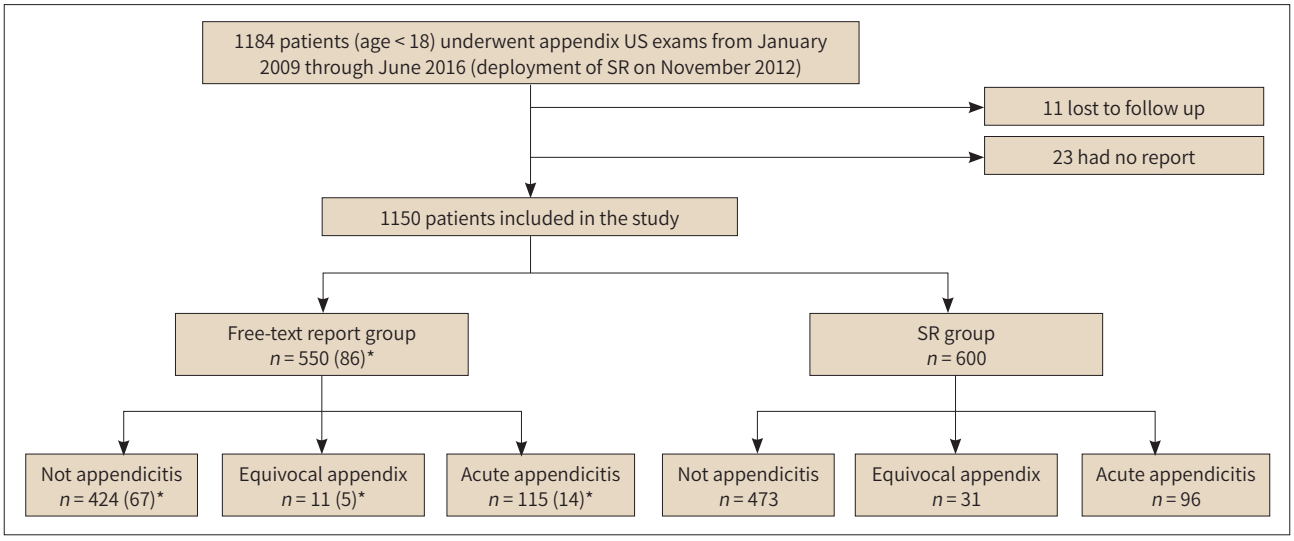
MATERIALS AND METHODS

Our Institutional Review Board approved this study and waived the requirement for informed consent (IRB No. 2020-09-002-001).

STUDY POPULATION

This retrospective study included 1184 pediatric patients younger than 18 years who underwent US for suspected acute appendicitis between January 2009 and June 2016. Of these patients, 34 were excluded due to follow-up loss (n = 11) or lack of report (n = 23). A total of 1150 patients comprised the final study population, and the patients were divided into two groups according to the US report form; the first group used free-text (n = 550), and the second used SR (n = 600). For the comparison of the two groups, each group was sub-classified into three simplified categories based on the likelihood of appendicitis: category 1, not appendicitis; category 2, equivocal appendix; category 3, acute appendicitis (Fig. 1). Category 1 (not appendicitis) included grade 1 (definitely non-appendicitis) and grade 2 (probably non-appendicitis) in the SR group and those with the description "normal appendix," "not appendicitis," or "probably not appendicitis" in the conclusion of the free-text group. Category 2 (equivocal ap-

Fig. 1. Flow diagram of the patients included.



*The number of exams performed after SR implementation but reported as free-text.
SR = structured report

pendix) included grade 3 (indeterminate) in the SR group and those with the description "equivocal or indeterminate appendix," "non-visible appendix," or "borderline dilatation of appendix" in the free-text group. Category 3 (acute appendicitis) included grade 4 (probably appendicitis) and grade 5 (definitely appendicitis) in the SR group, with the description "acute appendicitis," "mild appendicitis," or "tip appendicitis" in the free-text group.

DEVELOPMENT OF THE STRUCTURED REPORT TEMPLATE

The SR for the interpretation of appendix US was implemented by our institution in November 2012 and has since been used routinely in daily practice. It was based on a literature review (9-11) with information on the presence or absence of the following US exam findings: 1) non-compressible enlarged appendix (> 6 mm), 2) appendiceal wall thickening compared with the adjacent normal bowel wall, 3) US-guided tenderness, 4) increased echogenicity of the periappendiceal fat, and 5) increased vascularity of the appendiceal wall. Finally, the likelihood of appendicitis was scored using the five-point scale: grade 1, definitely non-appendicitis; grade 2, probably non-appendicitis; grade 3, indeterminate; grade 4, probably appendicitis; and grade 5, definitely appendicitis. The final decision on the likelihood of appendicitis relied on the performing radiologists' subjective impression instead of specific decision criteria.

US EXAMINATION

All US examinations were performed with an iU22 gray-scale US system (Philips Healthcare, Eindhoven, Netherlands) using 5–8 MHz curved or 5–12 MHz linear probes, followed by color Doppler US at low-flow settings of the lowest available pulse repetition frequency, the highest possible gain without background noise, and a 100 Hz low-wall filter. All US examinations were performed by residents (with 1–4 years of training) during daytime business hours under the supervision of experienced abdominal radiologists, or by the same attending ab-

dominal radiologists, using a graded-compression technique. As a routine clinical protocol, the appendix US examinations were not conducted by the radiologists during off-hours at our hospital.

REFERENCE STANDARD

The diagnosis of appendicitis was based on pathology reports which were based on the presence of neutrophil infiltration of the submucosa or muscularis propria. The absence of appendicitis was confirmed through pathologic analysis (negative appendectomy) or assumed based on information retrieved from the medical records in which appendicitis was not diagnosed in the 30 days after the initial presentation. NAR was defined as the proportion of patients with a normal appendix from all patients who underwent an appendectomy. PR was defined as the proportion of patients with a perforated appendix noted upon pathologic examination, from all patients with confirmed appendicitis upon histologic examination.

STATISTICAL ANALYSIS

Continuous variables were expressed in terms of the mean and standard deviation using Student's *t* tests. Proportions were compared using Fisher's exact tests or Pearson's chi-square tests as appropriate. Sensitivity, specificity, positive predictive value, negative predictive value (NPV), and accuracy of each group were also calculated. A *p*-value of less than 0.05 was considered statistically significant. All analyses were performed using PASW statistics for Windows (version 18.0; SPSS Inc., Chicago, IL, USA).

RESULTS

PATIENT DEMOGRAPHICS

Demographic data are shown in Table 1. In the SR group, the mean patient age was slightly higher than that in the free-text group. There was no difference in gender between the two

Table 1. Patient Demographics

	All (*n* = 1150)	Free-Text Group (*n* = 550, 47.8%)	Structured Report Group (*n* = 600, 52.2%)	*p*-Value
Age, years		10.0 ± 3.9	10.6 ± 3.7	0.008*
Sex				0.101†
Female	579 (50.3)	263 (47.8)	316 (52.7)	
Male	571 (49.7)	287 (52.2)	284 (47.3)	
Reported category				0.003†
Category 1 (not appendicitis)	897 (78.0)	424 (77.1)	473 (78.8)	
Category 2 (equivocal appendix)	42 (3.7)	11 (2.0)	31 (5.2)	
Category 3 (acute appendicitis)	211 (18.3)	115 (20.9)	96 (16.0)	
Rate of appendectomy	219 (19.0)	117 (21.3)	102 (17.0)	0.065†
Rate of appendicitis	192 (16.7)	98 (17.8)	94 (15.7)	0.328†

Data are presented as mean ± standard deviation or number (%).
*Student's *t* tes.
†Pearson chi-square test.

groups. Categories 1 and 2 were relatively more frequent in the SR group, and category 3 was relatively more frequent in the free-text group. In particular, category 2 in the SR group was more than twice as high as that in the free-text group. The rate of appendectomy was not significantly different between the two groups (free-text = 21.3% and SR = 17.0%, $p = 0.065$), and all appendectomy were performed in our institution. No significant difference was also observed in the incidence of appendicitis between both groups (free-text = 17.8% and SR = 15.7%, $p = 0.328$).

CLINICAL OUTCOMES (CT UTILIZATION RATE, NAR, AND PR)

Table 2 shows the frequencies of CT utilization rate, NAR, and PR of the two groups. After the introduction of the SR, the CT utilization rate following US examinations for establishing the diagnosis of appendicitis significantly decreased (free-text = 13.5% and SR = 8.2%, $p = 0.003$). Compared by category, CT utilization rate of categories 1 and 3 were significantly lower in the SR group than that in the free-text group (free-text = 9.0% and SR = 3.8%, $p = 0.001$; free-text = 24.3% and SR = 9.4%, $p = 0.003$, respectively).

Nineteen of 117 patients who underwent appendectomy in the free-text group had negative appendectomies, corresponding to 16.2% NAR. The pathological diagnoses in these 19 cases included serosal congestion ($n = 7$), fecal impaction ($n = 5$), serosal congestion with lymphoid hyperplasia ($n = 4$), lymphoid hyperplasia ($n = 2$), and cecal diverticulum ($n = 1$). Eight of 102 patients who underwent appendectomy in the SR group had negative appendectomies, corresponding to 7.8% NAR. The pathological diagnoses in these eight negative cases included serosal congestion ($n = 6$), lymphoid hyperplasia ($n = 1$), and fecal impaction ($n = 1$). NAR was significantly lower in the SR group than in the free-text group ($p = 0.028$). Category 3 of the free-text group yielded significantly higher NAR than the SR group ($p = 0.02$).

Appendiceal perforation on pathologic examination was present in 44 patients in the free-text group and 49 patients in the SR group. This difference was not statistically significant (37.6% and 48.0%, $p = 0.078$). There was no significant difference in PR between the two groups, even by category.

DIAGNOSTIC PERFORMANCE

The performance of each group for the diagnosis of appendicitis is shown in Table 3. Equivocal results (category 2) were eliminated from calculating performance because the calcula-

Table 2. The CT Rate, NAR, and PR of the Free-Text and SR Groups

Variable	Secondary CT			Negative Appendectomy			Perforation		
	Free-Text	SR	*p*-Value	Free-Text	SR	*p*-Value	Free-Text	SR	*p*-Value
Total	74/550	49/600	0.003	19/117	8/102	0.028	44/117	49/102	0.078
Category 1 (not appendicitis)	38/424	18/473	0.001	3/7	0/1	0.625	0/1	0/1	
Category 2 (equivocal)	8/11	22/31	0.618	1/2	3/7	0.722	1/2	2/7	0.583
Category 3 (acute appendicitis)	28/115	9/96	0.003	15/108	5/94	0.020	43/108	47/94	0.095

Data are given as number.
NAR = negative appendectomy rate, PR = perforation rate, SR = structured report

Table 3. Diagnostic Performance of the Free-Text and Structured Report Groups

Statistic (%)	Free-Text Group (*n* = 550)	Structured Report Group (*n* = 600)	*p*-Value
Sensitivity	95.88 (89.78–98.87)	98.89 (93.96–99.97)	0.002
Specificity	95.02 (92.56–96.85)	98.54 (97.01–99.41)	0.001
PPV	79.43 (71.94–85.33)	93.13 (86.67–96.59)	< 0.001
NPV	99.14 (97.78–99.67)	99.77 (98.44–99.97)	0.222
Accuracy	95.17 (93.00–96.82)	98.60 (97.25–99.39)	0.001

Data in parentheses are 95% confidence internals.
NPV = negative predictive value, PPV = positive predictive value

tion of accuracy (defined as true-positives plus true-negatives) could not reflect equivocal results. The use of SR significantly improved the diagnostic performance of US examinations between the free-text and SR group, with the exception of the NPV. NPV showed a statistically insignificant increase.

DISCUSSION

Free-text reports of radiologic studies have been criticized due to inherent deficiencies, including inconsistencies in content, structure, and nomenclature (12). The standardized SR system has greater clarity than free-text reports in the communication of imaging results to referring clinicians by improving consistency in reporting (4, 5). In particular, SR for the diagnosis of appendicitis was advocated for its simplicity and essentiality (13). Our proposed five-point scale SR on the radiologist's impression of the likelihood of appendicitis provides clearer guidance to clinicians about which cases need further imaging studies or clinical decisions. In addition, the objective checklist of imaging findings that are proven to be highly associated with appendicitis allows referring clinicians to understand the radiologist's rationale for the decision. In the present study, improved communication between radiologists and clinicians contributes to reducing NAR (16.2% and 7.8%, respectively), additional CT utilization rate (13.5% and 8.2%, respectively) and increasing diagnostic accuracy from 95.17% to 98.60%. These results correspond well with earlier studies using SR for the appendiceal US, which reported improved clinical outcomes, including lower CT use, lower NAR, and improved diagnostic accuracy (3, 6-8).

In our study, the CT utilization rate was significantly higher in categories 1 and 3 of the free-text group (free-text = 9.0% and SR = 3.8%, $p = 0.001$; free-text = 24.3% and SR = 9.4%, $p = 0.003$, respectively), while the NAR was higher in category 3 of the free-text group (free-text = 13.9% and SR = 5.3%, $p = 0.02$). However, both groups showed the highest CT utilization rate and NAR in equivocal studies (category 2) without significant difference. These results indicate that radiologically equivocal cases were misclassified as positive (category 3) or negative (category 1) results in the free-text reports because the likelihood of appendicitis in free-text reports is mainly based on binary decisions (Fig. 2).

NAR and PR are two important reciprocal measures of quality of care that represent false-positive and delayed diagnoses, respectively (14). Although delayed diagnosis of appendicitis can lead to increased morbidity from appendiceal perforation, unnecessary surgery carries

Fig. 2. An 11-year-old male with right lower quadrant pain.
A. Gray-scale US shows a mildly dilatated appendix in the distal portion (6.6 mm, arrows) but not appendiceal wall thickening.
B. There is no mural hyperemia on the color Doppler US image. The case was interpreted as suspicious tip appendicitis (category 3) in the free-text report. Laparoscopic appendectomy was performed, and the pathological results showed lymphoid hyperplasia and serosal congestion.

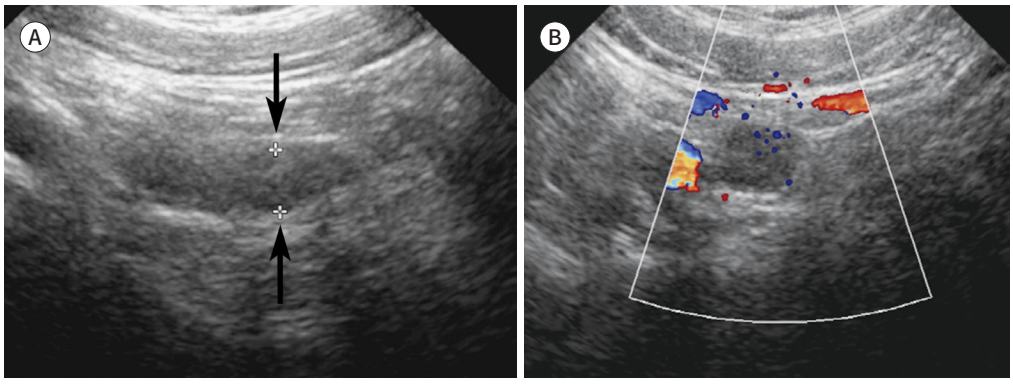
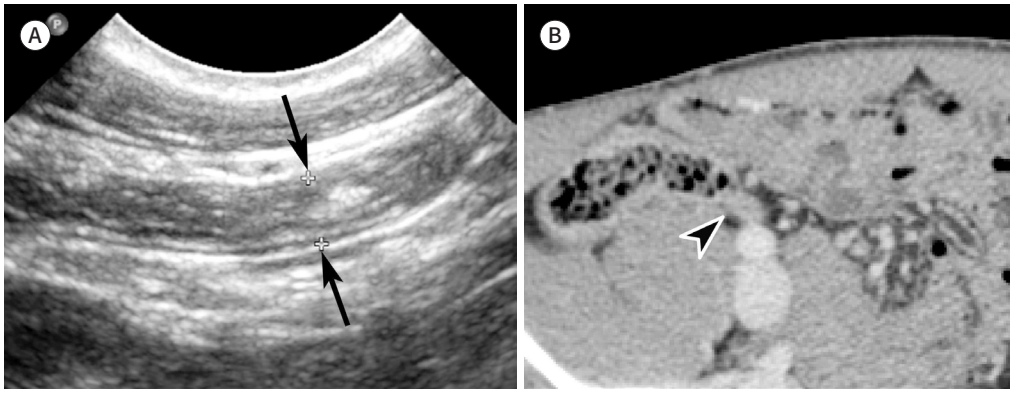


Fig. 3. A 15-year-old male with right lower quadrant pain.
A. Gray-scale US shows dilatation (6.8 mm, arrows) and wall thickening of the appendix in the distal portion. Equivocal hyperemia can be seen on the color Doppler US image. This case was described in a structured report as an equivocal appendix (category 2).
B. Contrast-enhanced CT acquired on the same day as the US shows a normal-sized appendix (arrowhead) with mild wall thickening in the other small bowel loops. This case was finally reported as not appendicitis. The US findings were presumed to be secondary findings due to enteritis. The patient's symptoms improved with conservative management.



major risks and substantial costs. Thus, it is important to avoid unnecessary appendectomy while minimizing the incidence of perforated appendicitis. In the present study, NAR significantly decreased after the introduction of SR without a significant increase in PR. The previous study by Nielson et al. (8) described a significant decrease in NAR by introduction of SR, but PR was not rendered.

The reason why SR improved clinical outcomes and diagnostic accuracy is thought to exist in the equivocal category because an equivocal interpretation carries a diagnostic value (Fig. 3). Previous studies have reported the use of SR incorporating equivocal categories for appendiceal US and its clinical validation. Larson et al. (6) developed a five-category scheme for US examination results of suspected appendicitis, which designated two equivocal categories and

showed an improvement in the diagnostic accuracy of US examinations. Fallon et al. (3) reported successful implementation of the US scoring system, which included equivocal category (Appy-Score 4). In the present study, after the application of SR incorporating equivocal categories, the accuracy of sonographic interpretations improved from 95.17% to 98.60%. Even if the absolute difference in accuracy between the two groups was relatively small (3.43%), this contributed to a 70% decrease in incorrect diagnoses (false positives and negatives).

The present study has several limitations. First, the retrospective nature of this study may have biases in patient selection and information. There is potential selection bias due to the study population of different periods, although the rate of appendicitis between the two groups was not significantly different (17.8% and 15.7%, respectively). Second, because part of the reporters changed between two periods, inter-observer variability of each period may have observer bias. Third, several examiners performed US for the long study period and the final decision of likelihood of appendicitis was made subjectively by the examiners, which might also incur observer bias. Finally, the present study was performed at a single institution with a relatively small population. Therefore, additional multi-center studies with larger populations are required to validate our results.

In conclusion, our SR of US examination for suspected pediatric appendicitis significantly decreases additional CT examination and negative appendectomy without an increase in appendiceal PR.

Author Contributions

Conceptualization, K.H.J., K.H.J., J.S.K., C.K.; data curation, C.K., C.J.Y., K.H.J.; formal analysis, K.H.J., C.K., C.J.Y.; methodology, K.H.J., J.S.K.; project administration, K.H.J., C.K.; software, C.K., C.J.Y.; supervision, K.H.J., J.S.K.; validation, K.H.J., K.H.J., J.S.K.; writing—original draft, C.K., K.H.J., C.J.Y.; and writing—review & editing, all authors.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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소아 충수 초음파 검사에서 구조화 판독문의 부가가치: 추가 CT 검사 및 음성 충수절제술의 관점에서

최건우[1] · 최지영[2] · 김혁중[1*] · 김현진[1] · 장석기[1]

목적 본 연구에서는 소아 충수 초음파에서 구조화 판독문을 이용하는 것의 증분가치를 보고자 하였다.

대상과 방법 이 후향적 연구에는 2009년 1월부터 2016년 6월 사이에 충수염이 의심되는 소아 환자 1150명이 포함됐다. 2012년 11월, 충수 초음파에 대한 5점 척도의 구조화 판독문을 도입했다. 환자들은 초음파 판독문 양식에 따라 자유 텍스트 그룹과 구조화 판독문 그룹으로 나뉘었다. 초음파 검사 후 추가적 CT 검사율, 음성 충수절제율 및 충수 천공률을 포함한 주요 임상 결과를 두 그룹 간에 비교했다.

결과 자유 텍스트 그룹에서 550명의 환자와 구조화 판독문 그룹에서 600명의 환자가 선별되었다. 추가 CT 검사 비율은 구조화 판독문 그룹에서 8.2%로 5.3%가 감소했다(p = 0.003). 음성 충수절제율은 구조화 판독문 그룹에서 7.8%로 8.4% 감소했다(p = 0.028). 충수 천공률(37.6% vs. 48.0%, p = 0.078)은 통계적으로 차이가 없었다.

결론 충수염이 의심되는 소아 환자에서 초음파 검사 시 구조화 판독문을 사용하면 추가 CT 검사율이 감소하고, 충수 천공률의 증가 없이 음성 충수절제율이 감소한다.

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APPENDIX

STRUCTURED REPORT FOR APPENDIX US

	Option	
Visualization of appendix	Grade 0. Not identified Grade 1. Unsure or partially visualized Grade 2. Clearly and entirely visualized	
Appendix maximal diameter, mm		
Appendiceal wall thickness, mm		
Non-compressible appendix	Absent	Present
Appendiceal wall thickening	Absent	Present
US-guided tenderness	Absent	Present
Increased echogenicity of the periappendiceal fat	Absent	Present
Increased vascularity of the appendiceal wall	Absent	Present
Alternative diagnosis		
Likelihood of appendicitis	Grade 1. Definitely absent. Clinical observation is recommended Grade 2. Probably absent. Clinical observation is recommended Grade 3. Indeterminate. Clinical observation or CT is recommended Grade 4. Probably present. Surgical exploration is recommended Grade 5. Definitely present. Surgical exploration is recommended	