Original Article

Accuracy of appendiceal sonography: influence of number of cases and working shift

Sornsupha Limchareon*, Watanya Jaidee**, Alisara Wongsuttilert*, Adisorn Boonyarit***, Akkaporn Wititvarodom*

Abstract

Introduction: It is uncertain whether accuracy in appendiceal sonography differs among radiologists who has different number of cases and night shift work has any impact on sonography performance.

Method: We reviewed appendiceal sonography in children between the ages of 1 - 16 years old with equivocal clinical findings of having appendicitis. Their cases were sent to hospital from January 2009 to December 2012 for a sonography evaluation. The final diagnosis was made at the pathological examination for operative patients or discharge diagnoses for non-operative patients. A number of sonography scans per each radiologist and sonography result time were recorded. The accuracy of sonography performed by each radiologist and result time were consequently compared and evaluated.

Result: Of the 428 exams, the appendix was identified in 270 cases. Of the visualized appendix cases, 250 (92.6%) sonography examinations were accurate. There were 20 general radiologists performing ultrasounds and the number of scans varied from 1 - 103. The difference in the number of cases among radiologists had no statistically significant effect on the accuracy of sonography. Working shift was classified by day shift and night shift. The day shift and night shift did not make a significant difference on the diagnostic accuracy.

Discussion and Conclusions: Number of cases or working shift had no significant influence on the diagnostic accuracy of sonography in childhood appendicitis. Appendiceal sonography is reliable and it should be the first imaging modality in children suspected of having appendicitis.

Key words: Appendicitis, Diagnostic performance, Sonography

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Introduction

Performance of physician in terms of experience may result in patient outcomes. Working shift, weekends or weekdays also effect on the performance.[1 - 3] It has been long accepted that sonography is highly operator - dependent. Lin et al.[4] demonstrated that a resident radiologist had significantly lower diagnostic performance than a staff radiologist for characterizing complex cystic focal liver lesion by sonography. Sonography competence test among radiology residents have shown progressive improvement of performance with increasing experience.[5] The American College of Radiology (ACR), Society for Pediatric Radiology (SPR) and Society of Radiologists in Ultrasound (SRU) guideline for performing and interpreting diagnostic ultrasound (US) examinations qualifies residents who have completed diagnostic residency and have participated in the "supervision and/or performance, interpretation, and reporting of 500 US examinations in the past 36 months" as successfully meeting criteria to perform independent US.[6]

Appendiceal sonography has a high accuracy (88%) to diagnose acute appendicitis (AA) in the hands of experienced radiologists.[7] Another article reported the efficacy of sonography in childhood appendicitis, showing a sensitivity of 71.2%, specificity of 97.7% and accuracy of 92.6%.[8] Although computed tomography (CT) has proved to have more accuracy than sonography for the diagnosis of pediatric AA,[9 - 10] sonography is preferred prior to CT due to lacking of ionizing radiation. Performing appendiceal sonography in some children who are not cooperative is technically difficult and time consuming. We hypothesized that performing appendiceal sonography in children during night shift when radiologist is fatigue[3] is less accurate than during day shift and less experienced radiologists yield less accurate than experienced radiologists. To date, there is no accepted learning curve for appendiceal sonography in children.

The first objective of this study was to investigate the influence of radiologist's experience in terms of number of cases on the diagnostic performance of AA in children. The second was to determine the impact of working shift when performing sonography on the sonography performance.

Method

Patients

This study was approved by the Ethic Committee at Burapha University, Number 19/2557. We reviewed medical records of the children age 1 - 16 years who presented at Emergency Department or Outpatient Department with acute abdominal pain suspected clinically of having AA and were sent to diagnostic radiology department for sonography of the abdomen from January 2009 to December 2012. The study was conducted at a 250-bed, private general hospital, located in an urban area of Eastern Thailand. Patients with clinically unequivocal appendicitis underwent operation without imaging studies. Children with the history of appendectomy were excluded. Children who refused to admit in the hospital or stayed less than 24 hours were also excluded from our study. Data included patient demographics, radiologist-performed sonography, sonography result time, sonography diagnosis, surgical diagnosis, pathological diagnosis and discharge diagnosis.

Sonography

General radiologists performed and interpreted the sonography. Sonography is available 24 hours a day, seven days a week. A day shift means the work shift occurring between 8.00 a.m. and 4.00 p.m. from Monday to Sunday. A night shift means the work shift occurring between 4.00 p.m. to 8.00 a.m. A radiologist who performed sonography during night shift was the same one who worked during the day shift and stayed on duty for 24 hours a day. Sonography was initially performed using the convex transducer 3 - 5 MHz (Aplio XG SSA-790A;

Toshiba, Osaka, Japan) for a general survey of the abdomen. Thereafter focused sonography of the appendix was performed using the linear transducer 5 - 12 MHz by using graded compression technique.[11] The maximal outer diameter (MOD) in axial plane of the appendix was measured. Sonography examinations were interpreted as AA when the MOD of the appendix was > 6 mm,[12] normal appendix when the MOD </= 6 mm, or non-visualized appendix when the appendix could not be identified. Our study did not consider secondary signs of AA included in the diagnosis of AA.[12] The decision about whether a patient should undergo surgery, observation or further examined by CT was made by a general surgeon based on the clinical, laboratory and sonography results. Confirmation of AA was made by surgical pathology. A negative diagnosis for AA was confirmed either a normal pathologic finding or with treatments of other conditions including admission for observation of the clinical symptoms and signs at least 24 hours prior to discharge from the hospital.

True-positive studies were considered if the sonography were positive and pathological results confirmed AA. False-positive results were considered if the pathological results revealed no AA or the child was discharged with a diagnosis other than AA. True-negative studies were considered if the sonography was negative and the pathological results showed no AA, or a negative diagnosis for AA in children who did not undergo surgery. False-negative studies referred to the negative sonography but underwent surgery, and the pathological results revealed AA.

Statistical analysis

In the visualized appendix cases, test characteristics (sensitivity, specificity, diagnostic accuracy, positive and negative predictive values) and their 95% confidence intervals (CI) were calculated.

These data have been published elsewhere.[8] Test characteristics of each radiologist were analyzed. Radiologist's experience was determined by number of sonography scans. Logistic regression was used to adjust the radiologists' scan numbers that affect to sonography diagnosis. ROC comparison between sonography diagnosis with radiologist's scan numbers and without radiologist's scan numbers was compared. Work shift was stratified by 8 hours. A comparison of test characteristics according to work shift was also calculated. Differences were test for significance by chi-square. A p-value < 0.05 was required for significance.

Result

Four hundred and twenty-eight sonography studies were enrolled. There were 220 boys and 208 girls, mean age 9 years (95% CI, 8.64 - 9.37). A total of 20 radiologists performed the sonography. Number of cases per each radiologist was shown in table 1. Sonography identified the appendix in 270 studies. The overall identification rate was 63.1%. Sonography was positive in 52 (19.3%) and negative in 218 (80.7%). The overall performance of sonography was presented in the Figure 1. Seventy-six children (17.8%) underwent surgery. Surgical pathologic results confirmed AA in 49 patients. In 27 patients, the results of appendectomy were negative for appendicitis. Thus, the negative appendectomy rate was 35.5%. There were 15 false-positive studies and 5 false-negative studies. There was no perforated appendicitis or mortality rate in our study.

Only visualized appendix cases were calculated. Sonography had an overall sensitivity of 88.1% (95% CI, 74.4 - 96.0%), specificity of 93.4% (95% CI, 89.4 - 96.3%), PPV of 71.2% (95% CI, 56.9 - 82.9%), NPV of 97.7% (95% CI, 94.7 - 99.3%) and accuracy of 92.6% (95% CI, 89.5 - 95.7%) for the diagnosis of AA. Number of sonography scans per radiologist was analyzed by logistic regression. The logistic model showed coefficient of sonography was 4.64 (95% CI: 3.57, 5.73). A comparison of the area under ROC curve of sonography diagnosis between

radiologist with scan numbers and without scan numbers showed no statistical difference (p-value = 0.733) as presented in table 2 and figure 2. Table 3. reveals 57.7% (247) of patients underwent sonography during a day shift and 42.3% (181) during a night shift. A comparison of test validity during day shift and night shift either before midnight or after midnight showed no significant difference as shown in table 4.

Table 1 Number of sonography scans per each radiologist

Radiologist	Number of sonography scans	Radiologist	Number of sonography scans
A	103	K	7
B	61	L	7
C	58	M	5
D	47	N	4
E	24	O	3
F	24	P	3
G	23	Q	2
H	22	R	2
I	17	S	1
J	14	T	1

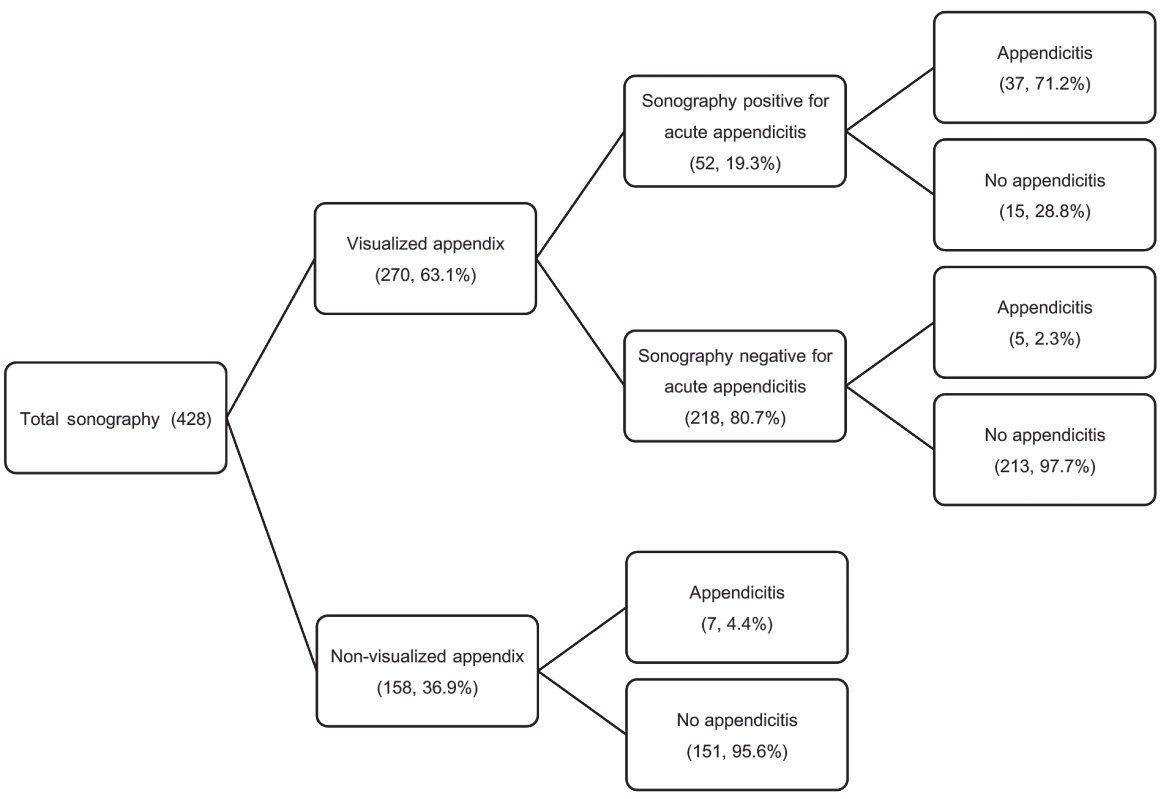

Figure 1 The overall sonography performance

Table 2 ROC comparison between sonography diagnosis with and without radiologist's scan numbers

Model	ROC	95% CI
Sonography with radiologist's scan numbers (p2)	0.913	0.855 - 0.971
Sonography without radiologist's scan numbers (p0)	0.908	0.855 - 0.960
χ^2 = 0.12 (1), p-value = 0.733		

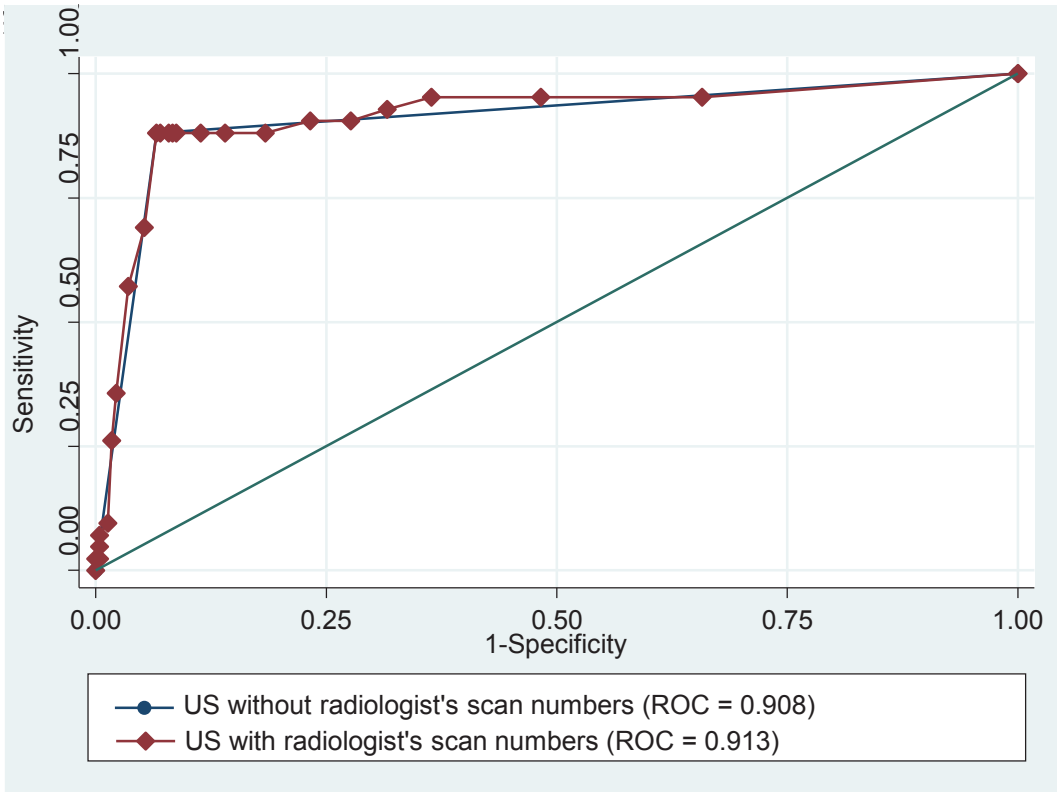

Figure 2 ROC for sonography diagnosis with radiologist's scan numbers and without radiologist's scan numbers

Table 3 Overall sonography results and time of diagnosis

Result time	Sonography result			Total
	positive	negative	non-visualized	
8.00 - 16.00	32 (13.0%)	139 (56.3%)	76 (30.8%)	247
16.00 - 24.00	15 (10.1%)	63 (42.3%)	71 (47.7%)	149
0.00 - 8.00	5 (15.6%)	16 (50.0%)	11 (34.4%)	32
Total	**52**	**218**	**158**	**428**

Table 4 Sonography findings and final diagnoses in visualized appendix cases compared with time of diagnosis

	Sonography at 8.00 - 16.00 (n = 171)			Sonography at 16.00 - 24.00 (n = 78)			Sonography at 0.00 - 8.00 (n = 21)			
Appendicitis	**+ve**	**-ve**	**Total**	**+ve**	**-ve**	**Total**	**+ve**	**-ve**	**Total**	**p-value**
Yes	22	3	25	11	2	13	4	0	4	
No	10	136	146	4	61	65	1	16	17	
Total	32	139	171	15	63	78	5	16	21	
Sensitivity (95% CI)	88.0% (68.8% - 97.5%)			84.6% (54.6% - 98.1%)			100.0% (39.8% - 100.0%)			0.153
Specificity (95% CI)	93.2% (87.8% - 96.7%)			93.8% (85.0% - 98.3%)			94.1% (71.3% - 99.9%)			0.896
PPV (95% CI)	68.8% (50.0% - 83.9%)			73.3% (44.9% - 92.2%)			80.0% (28.4% - 99.5%)			0.416
NPV (95% CI)	97.8% (93.8% - 99.6%)			96.8% (89.0% - 99.6%)			100.0% (79.4% - 100.0%)			0.732
Accuracy (95% CI)	92.4% (87.3% - 95.9%)			92.3% (84.0% - 97.1%)			95.2% (76.2% - 99.9%)			0.897

+ve = positive, -ve = negative

Among non-visualized appendix cases (158), 76 (48.1%) occurred during 8.00 - 16.00 shift, 71 (44.9%) occurred during the 16.00 - 24.00 shift and 11 (7%) occurred during 24.00 - 8.00 shift. Comparison of percentage between visualized and non-visualized appendix cases, the percentage of non-visualized appendix cases was highest during the 16.00 - 24.00 shift.

Discussion and Conclusion

There has been a variety of reported values of sensitivity and specificity of appendiceal sonography. One of the factors influencing on the variability is the performance of radiologists. Some institutions, radiologists perform sonography while the other institutions or the other period of time, technologists, physicians or radiology residents do. Even among radiologists, level of competence and experience are different. Our study demonstrated that radiologist's experience had no significant effect on the sonography diagnosis of AA in children. This was discordant with prior appendiceal sonography study which compared between radiologists performing sonography during day shift and technologists performing sonography during night shift. They found that sensitivity and PPV were significantly lower during night shift and they concluded that the poor sensitivity results were due to inadequate performance of the examination. That study also compared learning curve by years and found that most of the measures were increased in the following year.[13] In concordance with another report, showed that dedicated pediatric sonographers were able to identify the appendix at a significantly higher rate than general sonographers and the identification rate of appendix increased over time.[14] In contrast, another study compared accuracy of appendiceal sonography between pediatric surgeons trained abdominal sonography course only 3 days and the radiology department sonography. The accuracy of both groups was comparable but the number of patients in that study was very small.[15] As well as a prospective study in 147 patients from Taiwan showed a sensitivity of 96.4%, a specificity of 67.6%,

an accuracy of 89.1%, a PPV of 89.8%, and a NPV of 86.2% for the sonography diagnosis of AA performed by emergency physicians who had completed the fundamental gastrointestinal sonography training course and had more than 1 year experience on sonography examinations.[16] Thus, sonography diagnosis of AA is challenging. Physicians either radiologists or non-radiologists with adequate training can achieve high diagnostic performance. In some areas where shortage of radiologists, focus training for medical non-radiologic personnel can improve sonography performance and the necessity of CT may be declined. As observed by Trout et al.[14] that trend of subsequent CT ordering decreased when identification rate of appendix increased.

The minimum number of sonography examinations required for performance varies depending on the region of interest.[17] Only 20 trained sonography exams were adequate for physician who had no sonography experience to achieve excellent results in three easiest sonography targets including bladder, aorta and pleura.[17] Whereas in the difficult sonography targets, for example, to detect congenital heart defects in routine obstetric sonography, a study since 2006 classified sonographers as experienced enough when they performed > 2000 routine obstetric sonography examinations.[18] Another article studied pediatric emergency physicians who had experience in 100 - 150 general sonography examinations, without experience in bowel sonography, received a 1-hour focus training of bedside sonography for the diagnosis of intussusception, demonstrating a good diagnostic performance characteristics.[19] Chen et al.[16] suggested emergency physicians to perform sonography practice under supervision for 3 - 6 months and at least 50 cases for the diagnosis of AA by sonography as a minimal training. However our study revealed that number of sonography scans has no influence on the accuracy.

We noticed that more than one-third of appendiceal sonography was in night shift (47.3%) in our study. The two work shifts did not have significant effect on the accuracy of sonography for the diagnosis of AA in children in concordance with the finding of Doria et al.[2] that imaging examinations and interpretation were done by less experienced practitioners during night shift but the results were not different. In contrast to Trout et al.[14] that showed poorer diagnostic performance of sonography during night shift. Similar finding was reported from the clinical trial that patients with serious conditions admitted in night shift had a higher mortality rate than admitted in day shift.[1] This may be because imaging performance depends solely on radiologist while clinical care depends on multidisciplinary team which is often lower level of staffing during night shift.

From a total of 428 sonography investigations, only 49 (11.5%) had AA in our series. This study was conducted in the private general hospital, the using of diagnostic imaging may be from extra caution rather than necessity. A study from Brazil compared the treatment of AA between private and public hospitals. They also found that private hospitals used more diagnostic work up.[20]

Limitations

This study was limited by retrospective design. Lacking of follow-up in the non-operative patients might miss some atypical longer duration of AA. There might be some spontaneous resolving appendicitis in the sonography diagnosis of positive for AA, and were stated as false-positive. We did not consider body habitus of which certainly had effect on the sonography accuracy.[21] The duration of the sonography scan that might have more correlation with the accuracy than the work shift was not collected. Our study did not go in details in non-visualized appendix cases. Further work in this group is valuable. This was not a randomized study with largely normal patient group. A further large multicenter randomized trial should be done.

In our local expertise, radiologist's experienced level or working shift has no significant influence on the diagnosis of acute appendicitis in children. Thus

sonography for the diagnosis of acute appendicitis in children is reliable and should be the first imaging modality in children suspected of having appendicitis regardless of radiologist's experience or work shift. This result may be applied for emergency physicians or other medical non-radiologists. Focus training of appendiceal sonography for emergency physicians or other medical non-radiologists may help to increase accuracy of diagnosing acute appendicitis.

Conflicts of interest: The authors have no conflict of interest to disclose.

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บทคัดย่อ

ความแม่นยำของอัลตร้าซาวด์ในการวินิจฉัยไส้ติ่งอักเสบ: อิทธิพลของจำนวนผู้ป่วยและช่วงเวลาทำงาน

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ผู้ให้ติดต่อ: อาจารย์ แพทย์หญิงศรสุภา ลิ้มเจริญ สาขารังสีวิทยาและเวชศาสตร์นิวเคลียร์ คณะแพทยศาสตร์ มหาวิทยาลัยบูรพา ๑๖๙ ถนนลงหาดบางแสน ตำบลแสนสุข อำเภอเมือง จังหวัดชลบุรี ๒๐๑๓๑ โทรศัพท์ ๐๓๘๓๘๖๕๕๔ โทรสาร ๐๓๘๓๘๖๕๕๗ อีเมล sornsupha@hotmail.com

บทนำ: เป็นที่น่าสงสัยว่าจำนวนผู้ป่วยและช่วงเวลาที่ทำมีผลต่อความแม่นยำในการวินิจฉัยไส้ติ่งอักเสบในเด็กด้วยอัลตร้าซาวด์โดยรังสีแพทย์หรือไม่

วิธีการศึกษา: ทบทวนผลอัลตร้าซาวด์ของผู้ป่วยอายุ ๑ - ๑๖ ปี ที่สงสัยไส้ติ่งอักเสบ ตั้งแต่เดือนมกราคม พ.ศ. ๒๕๕๒ - เดือนธันวาคม พ.ศ. ๒๕๕๕ เปรียบเทียบกับผลทางพยาธิวิทยาในกรณีที่ผู้ป่วยได้รับการผ่าตัด หรือการวินิจฉัยก่อนผู้ป่วยออกจากโรงพยาบาล บันทึกจำนวนผู้ป่วยต่อรังสีแพทย์และเวลาขณะทำอัลตร้าซาวด์

ผลการศึกษา: จำนวนอัลตร้าซาวด์ทั้งหมด ๔๒๘ ราย อัลตร้าซาวด์พบไส้ติ่ง ๒๗๐ ราย กลุ่มที่พบไส้ติ่งอัลตร้าซาวด์วินิจฉัยถูกต้อง ๒๕๐ ราย (ร้อยละ ๙๒.๖) มีรังสีแพทย์ ๒๐ คน ทำอัลตร้าซาวด์จำนวนผู้ป่วยต่างๆ กันตั้งแต่ ๑ - ๑๐๓ รายต่อรังสีแพทย์ ๑ คน จำนวนผู้ป่วยที่ต่างกันไม่มีผลต่อความแม่นยำรายบุคคลในการวินิจฉัยไส้ติ่งอักเสบ เวลาขณะทำอัลตร้าซาวด์แบ่งเป็นในและนอกเวลาราชการ พบว่าเวลาขณะทำอัลตร้าซาวด์ไม่มีผลต่อความแม่นยำในการวินิจฉัยไส้ติ่งอักเสบ

วิจารณ์ และสรุปผลการศึกษา: ความแม่นยำในการวินิจฉัยไส้ติ่งอักเสบด้วยอัลตร้าซาวด์ไม่ขึ้นกับจำนวนผู้ป่วยหรือช่วงเวลา ดังนั้นการวินิจฉัยไส้ติ่งอักเสบด้วยอัลตร้าซาวด์มีความแม่นยำสูง ควรใช้เป็นเครื่องมือวินิจฉัยทางรังสีวิทยาอันดับแรกในผู้ป่วยเด็กที่สงสัยไส้ติ่งอักเสบ

คำสำคัญ: ไส้ติ่งอักเสบ, ความแม่นยำ, อัลตร้าซาวด์