Accuracy of ED Sonography in the Diagnosis of Acute Appendicitis

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The objective was to compare the accuracy of abdominal sonography performed by emergency physicians in the diagnosis of acute appendicitis with that of the surgeons' clinical impression. Three hundred-seventeen patients with right lower abdominal pain admitted to the Department of Emergency Medicine at National Taiwan University Hospital in Taipei, Taiwan were prospectively included in this study. Patients were divided into two groups according to the time of day they visited the emergency department. Those patients visiting the emergency department during the day were included in group I and those during the night were in group II. Group I was diagnosed by sonography. Group II was diagnosed by surgeons' clinical impression without sonographic examination. The definitive diagnosis of acute appendicitis was confirmed by the pathological reports. In the diagnosis of acute appendicitis, group I had a sensitivity of 96.4%, a specificity of 67.6%, a positive predictive value of 89.8%, a negative predictive value of 86.2%, and an accuracy of 89.1%, and group II had a sensitivity of 86.2%, a specificity of 37.0%, a positive predictive value of 74.6%, a negative predictive value of 55.6%, and an accuracy of 70.6%. The overall accuracy of sonography performed by emergency physicians in the diagnosis of acute appendicitis was superior to that of the surgeons' clinical impression. (Am J Emerg Med 2000;18:449-452. Copyright © 2000 by W.B. Saunders Company)

Acute appendicitis is one of the most common abdominal emergencies and is a challenging diagnosis in emergency practice. Although this disease entity has been recognized for more than 100 years, as of yet there has been no definitive test to diagnose an acute appendicitis. Many modalities have been used to aid the diagnosis of acute appendicitis, however, they are nonspecific and can not be used as a definitive test.[1-8] Several reports showed that when sonography is used to aid in the diagnosis of different diseases there has been high sensitivity, specificity, and accuracy.[4,7,9-11] Therefore, all physicians should consider training in sonography to use it within their practice. Thus, sonography performed by physicians, including internists, surgeons, gynecologists, pediatricians, and urologists has become a new trend in clinical practice. Abdominal sonography was first performed in 1981 to show the inflamed appendix.[12] Some studies have shown the promising value of sonography in the diagnosis of acute appendicitis.[4,9,13-18] Because radiologists are not always available in the emergency department, emergency sonography performed by emergency physicians is an inevitable clinical practice. To our knowledge, no study has compared the accuracy of sonography performed by emergency physicians with that of surgeons' clinical diagnosis.

In this study, we tried to determine whether abdominal sonography performed by emergency physicians in the diagnosis of acute appendicitis is superior to that of clinical impressions and as effective as that of radiologists.

MATERIALS AND METHODS

Between September 1997 and June 1999, 317 patients with right lower abdominal pain admitted to the Department of Emergency Medicine at the National Taiwan University Hospital (NTUH) in Taipei, Taiwan were prospectively enrolled on this study. When patients came to the Department of Emergency Medicine, they were first evaluated by one of the emergency physicians (emergency residency training in NTUH is a 5-year program). After taking a detailed history, performing a complete physical examination, and taking blood sample for complete blood count, a plain abdominal radiography examination was performed. Patients were divided into two groups according to the time of day they visited the emergency department.

Group I consisted of 147 patients admitted to the emergency department during the day shift (8 A.M. to 6 P.M.). If an acute appendicitis was diagnosed or suspected by emergency physicians, usually at the midresident level, they received further abdominal sonography examinations. Sonography was performed by staff members or senior emergency physicians, who had completed the fundamental gastrointestinal sonographic training course provided by The Society of Ultrasound in Medicine of the Republic of China (Table 1). They also had more than 12 months of experience on sonographic examinations. At the point of the maximal tenderness area, sonography was performed with a handheld 3.75 MHz curved array transducer (Toshiba SSA-340A, Tochigi-Ken, Japan) using graded compression technique in both longitudinal and transverse image.[9] The sonographic criteria of acute appendicitis are a noncompressible appendix with an anteroposterior diameter that is consistently 7 mm or greater, an appendicolith, and an interruption in the continuity of the echogenic submucosa, or a localized periappendiceal fluid collection.[17,18] Based on the sonographic findings, the patient was placed into one of three categories: (1) appendicitis, including suppurative, gangrenous, perforated, or tumor formation; (2) other diseases; or (3) normal abdominal sonographic screening.

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Manuscript received October 15, 1999, returned November 4, 1999, revision received December 9, 1999, accepted December 22, 1999.

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Key Words: Appendicitis, sonography, clinical impression.

0735-6757/00/1804-0019$10.00/0
doi:10.1053/ajem.2000.7343

TABLE 1. The Fundamental Gastrointestinal Sonographic Training Course

Basic physics and instrument in ultrasonography
Normal tomographic anatomy and examination technique in diagnostic abdominal ultrasound
Ultrasonography of the bowel great vessels, lymphoid system, mesentery, and abdominal well
Ultrasonography in diffuse parenchymal lesions of the liver, portal system, and spleen
Ultrasonography of the pancreas
Ultrasonography in focal lesions of the liver
Doppler ultrasound in digestive system
Ultrasonography of the gallbladder and biliary system
Ultrasonography of the general abdomen: surgical point of view
The impact of ultrasonography on other diagnostic modalities in abdominal diseases

Surgery was determined by the sonographic diagnosis. Patients with sonographic diagnosis of acute appendicitis were taken to surgery. Patients with other diseases diagnosed by sonography received appropriate treatment for their conditions. Patients with normal screenings were discharged from the hospital and were followed up at outpatient clinic within the following 2 weeks.

Group II consisted of 170 patients admitted to the emergency department during the night shift (6 P.M. to 8 A.M.). They received initial clinical examinations by senior emergency physicians. If an acute appendicitis was diagnosed or suspected, the patients received a follow-up examination by a senior surgical resident. No additional diagnostic test was arranged. Surgery was determined by the surgeons' clinical impression. Patients with a surgeon's clinical diagnosis of acute appendicitis were taken to surgery. Complete blood cell count and clinical examinations were repeated 4 hours later in patients with suspected clinical appendicitis. Surgery was arranged if appendicitis was later diagnosed. Those patients without appendicitis were discharged and followed up at outpatient clinic within the following 2 weeks.

The results of the sonographic examination and the surgeon's clinical diagnosis were analyzed to determine sensitivity, specificity, positive and negative predictive values, and overall accuracy. The definitive diagnosis of appendicitis was confirmed by the pathological reports. The statistical difference between the two groups in this study was determined by the logistic regression with analysis of maximum-likelihood estimates method. A P value of $< .05$ was considered significant.

RESULTS

Three hundred-seventeen patients were included in this study. There were 82 male (55.8%) and 65 female patients (44.2%) in group I and the mean age was 37.1 years (ages ranged from 8 to 84 years) (Table 2). Diagnostic results of graded compression sonography are shown in Table 3. The number of patients with sonographic diagnosis of appendicitis, other diseases and normal screening were 118 patients (80.3%), 12 patients (8.2%), and 17 patients (11.5%), respectively. Of the 118 patients, 106 underwent surgery and were proven to have appendicitis by the pathological examinations. Of the other 12 patients who underwent surgery without appendicitis, 9 were found to have a normal appendix, and 3 had fecal impaction. Among the other 12 patients with other diseases, 5 had pelvic inflammatory diseases, 3 had hydronephrosis, 2 had colitis, 1 had enteritis, and 1 had renal colic. One patient with colitis was proven to have appendicitis 3 days later. Three of 17 patients (17.6%) with normal sonographic screenings were found to have appendicitis during their second visit to the outpatient clinic.

TABLE 2. The Demographic of 317 Patients With Right Lower Abdominal Pain

	Group I	Group II
No. of patients	147	170
Visit time	8 AM-6 PM	6 PM-8 AM
M/F	82/65	99/71
Age (mean)	8-84 (37.1)	5-85 (35.5)

Group II had 99 male (58.2%) and 71 female patients (41.8%) and with a mean age of 35.5 years (ages ranged from 5 to 85 years). Of the 134 patients who underwent surgery; 100 patients had appendicitis, 30 patients had no identifiable pathological process and 4 patients were found to have other pathological intraabdominal processes at surgery, including 2 pelvic inflammatory diseases, 1 ovarian cyst, and 1 mesenteric lymphadenitis. Sixteen patients who were diagnosed without appendicitis by a surgeon were found to have appendicitis within 1 week at outpatient clinics and emergency departments which was confirmed during laparotomy.

A total of 110 (74.8%) patients with pathological findings were diagnosed with appendicitis in group I and 116 (68.2%) patients in group II. Both groups had approximately the same incidences of appendicitis. The overall sensitivity, specificity, positive predictive value, negative predictive value, and accuracy for sonographic examinations and surgeon's clinical impressions are displayed in Table 4. A comparison of calculations showed that sonography was superior to the surgeon's clinical impression in the diagnosis of appendicitis ($P < .005$).

DISCUSSION

Acute appendicitis is one of the most common abdominal emergencies requiring surgery. Over the past 100 years the mortality and morbidity rates related to this disease have been markedly reduced. A large measure of this progress has been the recognition of the serious effect of perforated appendicitis. Early surgical intervention has been recommended to prevent the perforation of the appendix; however,

TABLE 3. Correlation of Sonographic Examination and Pathological Reports

	Sonographic Examinations	Final Diagnosis	
		Appendicitis	Nonappendicitis
Appendicitis	118	106	12
Other diseases	12	1	11
Normal screening	17	3	14
Total	147	110	37

TABLE 4. A Comparison of Sonographic Examinations and Surgeons' Clinical Impression

	Sonographic Examinations	Surgeons' Clinical Impression
Sensitivity	96.4%	86.2%
Specificity	67.6%	37.0%
Positive predictive value	89.8%	74.6%
Negative predictive value	86.2%	55.6%
Accuracy	89.1%	70.6%

a high negative laparotomy rate was increased with aggressive surgical treatment. To prevent the delayed diagnosis, many modalities have been used to aid in the diagnosis of acute appendicitis.[1-4,7] Many studies have showed the promising value of sonography in the diagnosis of appendicitis. Although these results have been highly encouraging, no study has tested sonography performed by emergency physicians against the surgeons' clinical diagnosis.

Abdominal sonography examinations performed by staff radiologists have variable sensitivity, specificity, and accuracy in the diagnosis of acute appendicitis. These studies show a sensitivity of 36% to 99%, a specificity of 68% to 100%, and an accuracy of 64% to 96%.[5,9,11-16,19-30] Our emergency sonography performed by emergency physicians showed a sensitivity of 96.4%, a specificity of 67.6%, an accuracy of 89.1%, a positive predictive value of 89.8% and a negative predictive value of 86.2%. Our results are comparatively better than most other studies of abdominal examinations performed by radiologists. This study shows the reliability for emergency physicians to perform sonographic examinations provided that emergency physicians received sonography training and underwent a period of sonography practice. It is possible that if surgeons receive sonographic training, they will also have as good results as those of emergency physicians. If sonography is performed by surgeons and the sonographic diagnosis of appendicitis compared with their clinical impression, the results will be more accurate.

Studies have shown that the accuracy of sonographic examination is operator-dependent and requires skill and experience.[20,21,25] For an independent sonographer to perform sonography and interpret the sonographic results with accuracy, adequate training is required. We consider 3 to 6 months of sonographic practice under a skilled sonographer's supervision and at least 50 cases experience of sonographic diagnosis of appendicitis as a minimal training for a sonographer to show an accurate diagnosis of appendicitis. Several studies reported that allowing the patients themselves to localize the point of maximal tenderness with the sonography transducer expedited the examination and helped identify the intraabdominal pathologies.[9,16] There are two disadvantages of sonographic examinations.[31-33] First, the sonography beam can not penetrate gas and bone. Second, sonography is limited in obese patients. These drawbacks are likely to be amended with the advancement in electronic technology in the near future.

Three of 17 patients (17.6%) with normal sonographic screening were subsequently found to have appendicitis within the following 3 to 6 days. Wade et al[4] also reported that 24% of patients with normal screening were proven to have appendicitis. The reasons for these misdiagnoses may be attributed to early stages of appendicitis with minimal edematous change which failed to meet the diagnostic criteria, edematous appendix masked by bowel gases, inexperienced sonographers, or the working limitations of sonography. Repeated sonographic examinations of patients with normal screenings were suggested when their symptoms continued to persist after 4 to 6 hours of observation. One patient with appendicitis was misdiagnosed as colitis by sonography. The reactive thickness of colonic wall adjacent to the inflammatory appendix resulted in the sonographic misdiagnosis of colitis. More attention should be paid to patients with sonographic diagnosis of colitis which is localized in the cecal area.

There are two drawbacks in this study. This is not a randomized study but patients comprised a convenience sample. Daily emergency visits in our department are approximately 250 patients. More than six emergency physicians staff work during the day shift and only one works during the night shift. It is difficult for the emergency physician staff to perform sonography at night. Therefore, only those patients who came to the emergency department during the day received sonographic examinations. Another drawback is lacking for follow-up on all patients not taken to surgery. Only those patients their symptoms recurrence came to outpatient clinics.

In conclusion, on the basis of our results, we have found that sonography performed by an emergency physician in the diagnosis of acute appendicitis is superior to that of a surgeon's clinical impression. We suggest that sonographic training should be included in the emergency residency and surgical residency training program. However, it is crucial to remember that sonography cannot be completely relied on and sonographic findings should be incorporated with other clinical information about the patient to prevent misdiagnoses.

REFERENCES

1. Thompson MM, Underwood MJ, Dookeran KA, et al: Role of sequential leucocyte counts and C-reactive protein measurements in acute appendicitis. Br J Sury 1992;79:822-827
2. Dueholm S, Bagi P, Bud M: Laboratory aid in the diagnosis of acute appendicitis. Dis Colon Rectum 1989;32:855-859
3. Chen SC, Wang SM: C-reactive protein in the diagnosis of acute appendicitis. Am J Emerg Med 1996;14:101-103
4. Wade CD, Morrow SE, Balsara ZN, et al: Accuracy of ultrasound in the diagnosis of acute appendicitis compared with the surgeon clinical impression. Arch Surg 1993;128:1039-1047
5. Ohmann C, Yang Q, Franke C: Diagnostic scores for acute appendicitis. Eur J Surg 1995;161:273-281
6. Alvarado A: A practical score for the early diagnosis of acute appendicitis. Ann Emerg Med 1986;15:557-564
7. Balthazar EJ, Birnbaum BA, Yee J, et al: Acute appendicitis: CT and US correlation in 100 patients. Radiology 1994;190:31-35
8. Federle MP: Focused appendix CT technique: A commentary. Radiology 1997;202:20-21
9. Chen SC, Chen KM, Wang SM, et al: Abdominal sonography screening of clinically diagnosed or suspected appendicitis before surgery. World J Surg 1998;22:449-452
10. Berge LN, Marton V, Tranebjaerg L, et al: Prenatal diagnosis of osteogenesis imperfecta. Acta Obstet Gynecol Scand 1995;74:312-313
11. Gorcsan J, Lazar JM, Schulman DS, et al: Comparison of left ventricular function by echocardiographic automated border detection and radionuclide ejection fraction. Am J Cardiol 1993;72:810-815

12. Deutsch A, Leopold RG: Ultrasonic demonstration of the inflamed appendix. Radiology 1981;140:163-164

13. Crady SK, Jones JS, Wyn T, et al: Clinical validity of ultrasound in children with suspected appendicitis. Ann Emerg Med 1993;22: 1125-1129

14. Chesbrough RM, Burkhard TK, Balsara ZN, et al: Self-localization in US of appendicitis: An addition to graded compression. Radiology 1993;187:349-351

15. John H, Neff U, Kelemen M: Appendicitis diagnosis: Clinical and ultrasonic deductions. World J Surg 1993;17:243-249

16. Puylaert JBCM, Rutgers PH, Lalisang RI, et al: A prospective study of ultrasonography in the diagnosis of appendicitis. N Engl J Med 1987;317:666-669

17. Jeffrey RB, Jain KA, Nghiem HV: Sonographic diagnosis of acute appendicitis: interpretive pitfalls. Am J Radiol 1994;162:55-59

18. Yacoe ME, Jeffrey RB: Sonography of appendicitis and diverticulitis. Radiol Clin North Am 1994;32:899-912

19. Jahn H, Mathiesen FK, Neckelmann K, et al: Comparison of clinical judgment and diagnostic ultrasonography in the diagnosis of acute appendicitis: Experience with a score-aided diagnosis. Eur J Surg 1997;163:433-443

20. Skaane P, Schistad O, Amaland PF, et al: Routine ultrasonography in the diagnosis of acute appendicitis: A valuable tool in daily practice? Am Surg 1997;63:937-942

21. Franke C, Bohner H, Yang Q, Ohmann C, Roher HD: Ultrasonography for diagnosis of acute appendicitis: Results of a prospective multicenter trial. World J Surg 1999;23:141-146

22. Zielke A, Hasse C, Sitter H, et al: ''Surgical'' ultrasound in suspected acute appendicitis. Surg Endosc 1997;11:362-365

23. Rice HE, Arbesman M, Martin DJ, et al: Does early ultrasonography affect management of pediatric appendicitis? A prospective analysis. J Pediatr Surg 1999;34:754-759

24. Schwerk WB, Wichtrup B, Ruschoff J, et al: Acute and perforated appendicitis: Current experience with ultrasound-aided diagnosis. World J Surg 1990;14:271-276

25. Rao PM, Boland GWL: Imaging of acute right lower abdominal quadrant pain. Clin Radiol 1998;53:639-649

26. Carrico CW, Fenton LZ, Tayor GA, et al: Impact of sonography on the diagnosis and treatment of acute lower abdominal pain in children and young adults. AJR Am J Roentgenol 1999;172:513-516

27. Skaane P, Amland PF, Nordshus T, et al: Ultrasonography in patients with suspected acute appendicitis: A prospective study. Brit J Radiol 1990;63:787-793

28. Borushok KF, Jeffrey Jr RB, Laing FC, et al: Sonographic diagnosis of perforation in patients with acute appendicitis. AJR Am J Roentgenol 1990;154:275-278

29. Rioux M: Sonographic detection of the normal and abnormal appendix. AJR Am J Roentgenol 1992;158:773-778

30. Ford RD, Passinault WJ, Morse ME: Diagnostic ultrasound for suspected appendicitis: Does the added cost produce a better outcome? Am Surg 1994;60:895-898

31. Puylaert JBCM, Zant FM, Rijke AM: Sonography and the acute abdomen: Practical considerations. Am J Radiol 1997;168:179-187

32. Puylaert JBCM: Ultrasound of Appendicitis and its Differential Diagnosis. Berlin, Springer, 1990, pp 1-56

33. Heller M, Jehle DJ: Ultrasound in Emergency Medicine. Philadelphia, W.B. Saunders, 1995, pp 1-40