Gastrointest Radiol 11:334–338 (1986)

Gastrointestinal Radiology

Diagnostic Accuracy of Ultrasound in Acute Cholecystitis

Antonio Martínez, Xavier Bona, Martín Velasco, and Julio Martín
Department of Diagnostic Radiology, Hospital of Sant Pau, Universidad Autónoma, Barcelona, Spain

Abstract. This work attempts to assess the diagnostic accuracy of ultrasound for acute cholecystitis in 98 clinically suspected patients from the emergency unit in whom at least 3 of 6 relevant criteria are present. Gallbladder distention to 5 cm or more transversely or in the anterior–posterior axis (criterion 1) was present in 64 patients; thickening of the gallbladder wall of at least 5 mm (criterion 2) in 95; cholelithiasis (criterion 3) in 86; sonolucent halo in the gallbladder wall (criterion 4) in 40; sonolucent fluid band surrounding the gallbladder (criterion 5) in 27; and intraluminal echogenic mass with no posterior acoustic shadow (criterion 6) in 35. A diagnostic accuracy index, corrected for chance, was statistically and clinically more relevant with 3 as the minimum number of criteria for the ultrasonic diagnosis of acute cholecystitis.

Key words: Cholecystitis, acute – Gallbladder – Ultrasound, gallbladder.

Modern ultrasound (US) examination of the gallbladder is an effective tool in the diagnosis of acute cholecystitis (AC), especially when used on patients admitted for emergency surgery [1–4]. Cholescintigraphy (CS) and US are the first diagnostic imaging modalities that should be used [5, 6]. Only when ultrasound and scintigraphic signs are unsatisfactory or equivocal [7] would it be necessary to perform computed tomography (CT).

With the new real-time scanners, US examination of the gallbladder has become an area of great clinical development. Real-time scanners permit quick and easy visualization of the gallbladder in the majority of patients. Calculi approximately 1 mm in diameter can be imaged under ideal circumstances [8]. Acute cholecystitis usually results from obstruction of the gallbladder neck, with subsequent infection. The gallbladder therefore appears abnormally distended and spherical in shape and the gallbladder wall is edematous and thickened [9]. All these features, including the obstructing calculus, can be imaged by US and may be extremely valuable in correctly establishing the diagnosis.

Nevertheless, the precise US signs necessary for an accurate differential diagnosis of AC are still not defined. To make the correct therapeutic decisions in emergency conditions, we strove to establish the diagnostic value of US signs depending on the minimum number of signs present, regardless of their nature.

Material and Methods

Ultrasonic confirmatory studies were performed over 14 months on 98 patients from the emergency care unit who were clinically suspected of having AC (upper abdominal pain, fever, and leukocytosis). Of these patients, 69 were men and 31 were women, aged between 31 and 89 years (mean, 69). With 3 or more of 6 criteria, the diagnosis was confirmed in the majority of cases. These criteria of ultrasonic signs were (Figs. 1, 2): (1) gallbladder distention to 5 cm or more transversely or in the anterior–posterior axis; (2) thickening of gallbladder wall to 5 mm or more; (3) cholelithiasis; (4) sonolucent halo in the gallbladder wall; (5) fluid sonolucent band surrounding the gallbladder; (6) intraluminal echogenic mass.

The true condition (definitive diagnosis) was determined in all patients by surgery and pathologic examination.

The ultrasonic examinations were performed on linear electronic real-time equipment with a transducer frequency of 3.5 MHz. Cross-sections were made transversely, longitudinally, and obliquely, with the patient lying on his or her left side.

The standard indices of sensitivity, specificity, and positive and negative predictive value [10, 11] were calculated for every

Address reprint requests to: Antonio Martínez, Department of Diagnostic Radiology, Hospital de Sant Pau, Universidad Autónoma, Avda. S. Antonio M. Claret, 167, 08025 Barcelona, Spain

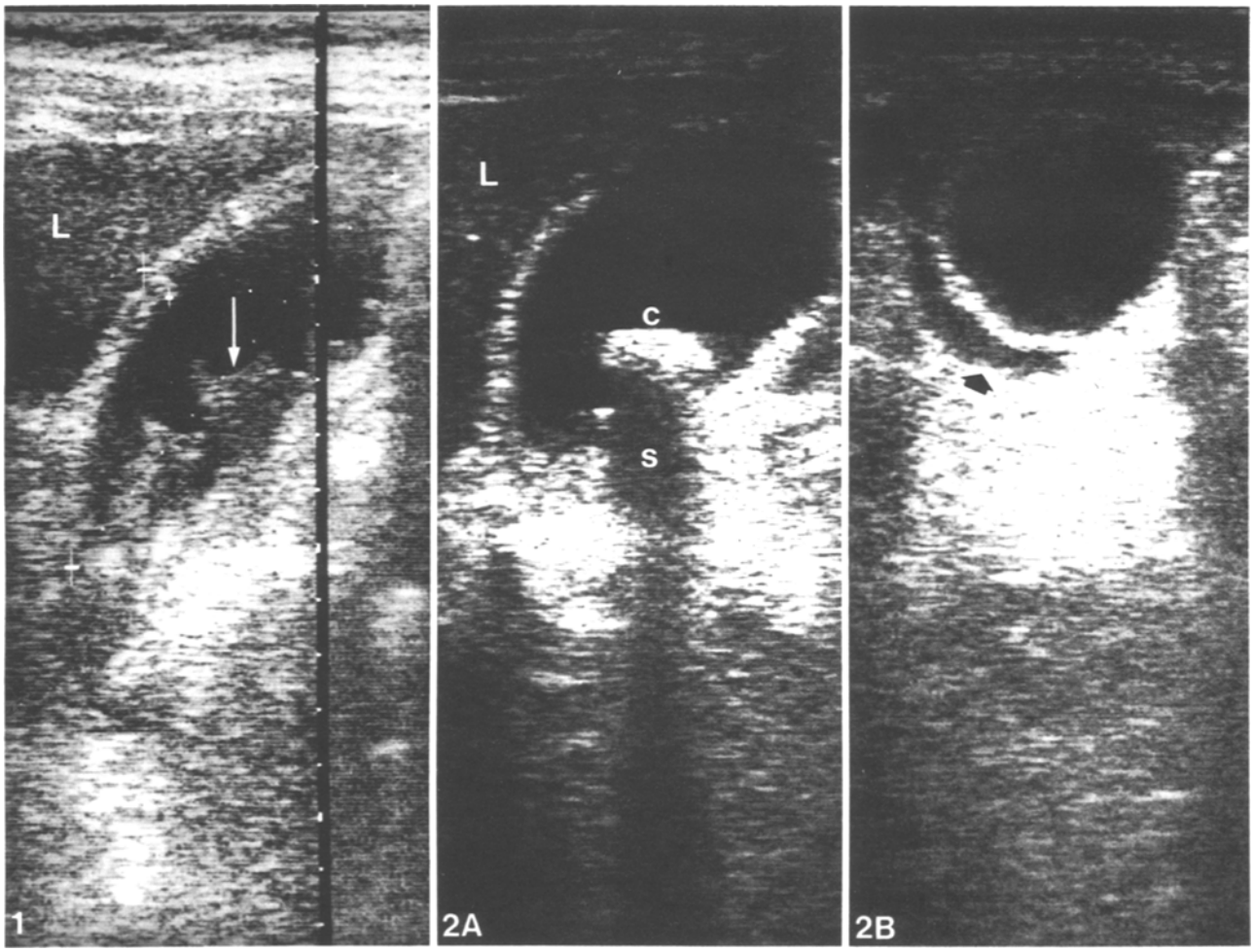

Fig. 1. Acute cholecystitis with empyema and calculi (3 criteria). Thickening of the gallbladder wall with focal sonolucent halo into it (+); intraluminal echogenic mass (*arrow*) with no posterior acoustic shadow corresponding to empyema. *L*, liver.

Fig. 2. Acute cholecystitis with pericholecystitic abscess and calculi (4 criteria). **A** Calculi (*c*) with acoustic shadow (*s*); L, liver. **B** Liquid band surrounding the gallbladder wall (*arrow*) corresponds to pericholecystitic abscess in this case. Note the distended gallbladder and thickening of the gallbladder wall.

minimum number of exigible criteria (MNC) present (6 possibilities).

Cohen's kappa (κ) [12, 13] was used to assess the observed test results (with every MNC) corrected for those expected by chance and was tested for its statistical significance against 0 by the normal standard critical ratio (z) with a confidence level set at 0.95 ($p<0.05$).

The ROC curve (Fig. 3) was devised to improve the decision analysis on the more recommendable MNC, according to the criteria of McNeil et al. [14].

Table 1. Frequency distribution of relevant US criteria

Criterion number	Patients ($N=98$)
1	64
2	95
3	86
4	40
5	27
6	35

Results

Frequency distribution by criterion number is shown in Table 1.

Different results in the test accuracy are obtained according to the MNC used (Table 2). When the MNC increases, the sensitivity decreases (especially over 3 criteria) and the specificity increases, as does the positive predictive value. However, the negative predictive value is maximum (0.5) at 3 MNC.

The diagnostic accuracy of the test (p_0) was never very high, and correcting the values for

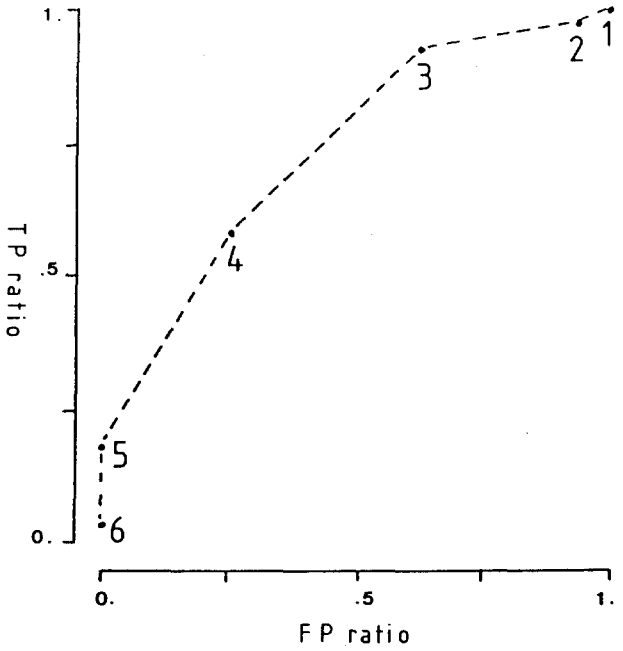

Fig. 3. An ROC curve. The minimum number of criteria used to intake a decision is indicated at each point. FP ratio, false-positive ratio (specificity). TP ratio, true-positive ratio (sensitivity).

Table 3. Frequency distribution of the number of criteria present

Number of criteria	Frequency
1[a]	3[b]
2[c]	9[d]
3	34[e]
4	37[f]
5	12
6	3
Total	98

[a] Implicated criterion 2 or 3.
[b] Implicated criterion (in combination of two) 1, 2, 3, or 6 (never 4 or 5).
[c] Doubtful surgical confirmation in 2 cases; the most unfavorable solution is to be preferred and they are taken as false negatives. The other case is a true negative without gallbladder pathology, but the patient underwent emergency surgery following clinical symptoms (see text).
[d] Emergency surgery was undertaken in 3 of 4 false negatives because of clinical symptoms and/or the magnitude of the criteria present. Five true negatives had chronic cholecystitis.
[e] Chronic cholecystitis with calculi in 5 and carcinoma in 1 false positive.
[f] Chronic cholecystitis with calculi in 3 and carcinoma in 1 false positive.

Table 2. Evaluation of the ultrasonic diagnosis of acute cholecystitis depending on the minimum number of criteria (MNC) present

MNC	TP	FP	FN	TN	Sensitivity	Specificity	PPV	NPV	P_0	κ	$s \cdot e_0(\kappa)$	Z
1	82	16	0	0	1.000	0.000	0.837	undeter.	0.837	0.000	–	–
2	80	15	2	1	0.976	0.063	0.842	0.333	0.8027	0.057	0.0700	0.809 (NS)
3	76	10	6	6	0.927	0.375	0.884	0.500	0.837	0.336	0.0996	3.369 ($p<0.005$)
4	48	4	34	12	0.585	0.750	0.923	0.261	0.612	0.191	0.0777	2.459 ($p<0.02$)
5	15	0	67	16	0.183	1.000	1.000	0.193	0.316	0.068	0.0366	1.860 (NS)
6	3	0	79	16	0.037	1.000	1.000	0.168	0.194	0.012	0.0158	0.777 (NS)

Prevalence rate of acute cholecystitis (TP + FN) = 0.837.

TP, true positives; FP, false positives; FN, false negatives; TN, true negatives; PPV, positive predictive value; NPV, negative predictive value; P_0, observed proportion (test results); κ, Cohen's Kappa; $s \cdot e_0(\kappa)$, standard error of Kappa; Z, critical value of the normal standard distribution; (NS), nonsignificant; (p), probability of first-kind error.

chance (K) lowered them to a great extent. Kappa was not statistically significant for MNC equal to 1, 2, 5, or 6, and the highest degree of agreement between test results and true condition is when MNC equals 3. The final decision was taken with 3 as the MNC.

False positives (10.2%) correspond to diagnoses of chronic cholecystitis or carcinoma. False (6.1%) and true negatives (TN) were also assessed using the magnitude of clinical symptoms and/or the present criteria, reducing false negatives (FN) to 3.0% for practical purposes, but increasing slightly (1 more case) false positives (FP) to 11.2% for surgical purposes. Table 3 shows the frequency distribution of the number of criteria present. The final diagnosis and outcome for FP, FN, and TN are detailed together with some other comments.

The ROC curve (Fig. 3) shows the relation between sensitivity and specificity (1-FP ratio). The greatest sensitivity is recommendable here, since a FP does not result in an erroneous therapeutic decision, while a FN entails a serious vital compromise [15].

Nevertheless, no surgical intervention or elective surgery is preferred over emergency surgery because of the lower surgical risk of the former. The higher the risk, the more the specificity is to be considered.

Discussion

The sensitivity and specificity of US in suspected AC were 81.4% and 60.2%, respectively, in 1 series, with a positive predictive value of 51.6% [16].

By CS, the specificity and sensitivity were reported to be as high as 99.2% and 95.2%, respectively [17, 18] but the examination is normal in the majority of cases of chronic cholecystitis; only the delayed filling of the gallbladder at 1 and 4 h is a useful indicator [10]. In general, US is more sensitive than CS in the study of gallbladder pathology, since it more easily differentiates between acute and chronic cholecystitis and demonstrates the presence of calculus [6]. At the same time, US can detect signs of complications associated with acute cholecystitis [3].

Computed tomography uses similar diagnostic criteria for AC but in many cases studies must be made before and after intravenous injection of the contrast medium [19]. Diagnostic reliability is very similar to that of US, although there are technical disadvantages since CT is a slower and more costly examination than sonography. The possibility of carrying out sonographic examination with a portable unit at the patient's bedside coupled with the high diagnostic reliability and low cost of this examination mean that US should be used as a preliminary visual study in patients suspected of having AC.

If we look at the frequency of each ultrasonic criterion (Table 1), we observe that distention of the gallbladder (criterion 1) is not a constant (64 patients), probably because it depends on when the diagnosis of AC is made. Thickening of the gallbladder of 5 mm or more (criterion 2) was present in 95 patients. Apart from the relevance of this sign, it is necessary to recognize its slight specificity in AC; it can be found in other pathologic conditions [20, 21]. Chronic cholecystitis may cause thickening of the gallbladder wall, although this usually occurs in an abnormally small gallbladder [22–24].

Cholelithiasis (criterion 3) was present in 86 patients. To consider its specificity for AC as a diagnostic tool is not recommendable because it also occurs frequently in chronic cholecystitis, and is routinely encountered in the general population. Certainly, calculi are the main cause of gallbladder obstruction but they are not always imaged by US, especially when they are small or hidden by the neck shadow. In fact, 8 of 10 false-positive findings had chronic cholecystitis due to calculi (the other were gallbladder carcinomas), and 3 of 6 patients with false-negative findings had no calculi. Lithiasis, when present alone, calls for elective surgery; emergency surgery is only justifiable because of its lower cost and if similar risk could be warranted.

We consider criteria 4, 5, and 6 as major signs of AC complications; they are found in lower proportions (40, 27, and 35 patients, respectively) than criteria 1–3. As for gallbladder distention, its presence depends on the time of evolution of the inflammatory disease and its early diagnosis. However, overemphasis of those criteria in order to establish the presence of AC, particularly pericholecystitis and empyema (criteria 5 and 6), although a tentative policy, is not likely to improve the accuracy of the test without adding more complexity. Criteria 4, 5, and 6 were usually found with 2 or more other criteria, except for 3 patients with only criteria 2 and 6. For these negative test results, it is useful to consider the relative relevance of empyema.

In general, the earlier the surgery, the lower the risk of perforation and mortality in patients with AC; a more sensitive test will thus decrease this risk. Current assessment of clinical signs (upper abdominal pain, fever, and leukocytosis, with or without Murphy's sign) has a high sensitivity and is a screening test for suspected AC.

This condition needs to be confirmed systematically because in some cases elective surgery would be preferred (less surgical risk) and in some exceptions a clinical follow-up would suffice. However, because a high sensitivity is still preferred over specificity, the test will serve as an exclusion test (the higher the negative predictive value, the better) in performing emergency surgery if AC is not excluded.

Unfortunately, the highest global accuracy of the test (corrected for chance) is achieved when 3 is the MNC. Although this is highly significant, it only represents a poor to fair agreement beyond chance between the test results and true condition. To perform another confirmatory test, namely cholescintigraphy, will be then justified only on patients in whom US is not diagnostic. The possibility of testing the gallbladder function to improve the diagnostic value of the US technique could also be considered. Contractility of the gallbladder and patency of the cystic duct can be confirmed by US examinations before and after a fatty meal [25], as we recently tried with ceruletide, an available cholecystokinin-like decapeptide [26].

Acknowledgments. The authors thank Carme Pujol and Rosana Larrosa for manuscript preparation and Linda Johnson for translation assistance.

References

1. Bergman AB, Neiman HL, Krant B: Ultrasonographic evaluation of pericholecystic abscesses. *AJR 132:*201–203, 1979
2. Kane RA: Ultrasonographic diagnosis of gangrenous cholecystitis and empyema of the gallbladder. *Radiology 134:* 191–194, 1980
3. Martinez A, Caceres J, Perez C: Postoperative acute cholecystitis: sonographic diagnosis. *Eur J Radiol 5:*35–37, 1985
4. Martinez A, Rosell R: Ultrasonographic criteria in the diagnosis of acute cholecystitis. *Radiología 25:*125–130, 1983
5. Laing FC, Federle MP, Jeffrey EB, Brown TW: Ultrasonic evaluation of patients with acute right upper quadrant pain. *Radiology 140:*449–455, 1981
6. Whorthen NJ, Uszler JM, Funamura JL: Cholecystitis: prospective evaluation of sonography and 99m Tc-HIDA cholescintigraphy. *AJR 137:*973–978, 1981
7. Kane RA, Costello PH, Diszlak E: Computed tomography in acute cholecystitis: new observations. *AJR 141:*697–701, 1983
8. Hessle PC, Hill DS, Deforte FM, Rocco AF: High accuracy sonographic recognition of gallstones. *AJR 136:*517–520, 1981
9. Croce F, Mantali G, Solbiati L, Marinoni G: Sonography in acute cholecystitis. *Br J Radiol 54:*927–931, 1981
10. Sondik EJ: Clinical evaluation of test strategies. *Clin Lab Med 2:*821–833, 1982
11. Feinstein AR: Clinical biostatistics. XXXI. On the sensitivity, specificity and discrimination of diagnostic tests. *Clin Pharmacol Ther 17:*104–116, 1974
12. Fleiss JL: *Statistical Methods for Rates and Proportions*, 2nd ed. New York: John Wiley, 1981
13. Cohen J: Weighted kappa: nominal scale agreement with provision for scaled disagreement on partial credit. *Psychol Bull 70:*213–219, 1968
14. McNeil BS, Keeler E, Adelstein SJ: Primer on certain elements of medical decision-making. *N Engl J Med 293:*211–215, 1975
15. Ransohoff DF, Feinstein AR: Problems of spectrum and bias in evaluating the efficacy of diagnostic tests. *N Engl J Med 299:*926–930, 1978
16. Freitas JE: Cholescintigraphy in acute and chronic cholecystitis. *Semin Nucl Med 12:*18–28, 1982
17. Weissman HS, Badia J, Sugarman LA, Kerger L, Rosenblatt R, Freeman LM: Spectrum of 99 Tc^m-IDA cholescintigraphic patterns in acute cholecystitis. *Radiology 138:*167–175, 1981
18. Davies ER: Radionuclide investigations. *Clin Gastroenterol 130:*205–233, 1983
19. Solomon A, Kreel L, Pinto D: Contrast computed tomography in the diagnosis of acute cholecystitis. *Radiology 134:*815–819, 1980
20. Fiske CE, Laing FC, Brown TW: Ultrasonographic evidence of gallbladder wall thickening in association with hypoalbuminemia. *Radiology 135:*713–716, 1980
21. Handler SJ: Ultrasound of gallbladder wall thickening and its relation to cholecystitis. *AJR 132:*581–585, 1979
22. Schalaer WI, Leopold GR, Scheible FW: Sonography of the thickened gallbladder wall: a non-specific finding. *AJR 736:*337–339, 1981
23. Engel JM, Deitch EA, Sikkema W: Gallbladder wall thickness: sonographic accuracy and relation to disease. *AJR 134:*907–909, 1980
24. Mindell HJ, Ring BA: Gallbladder wall thickening: ultrasonic findings. *Radiology 133:*699–701, 1979
25. Palframan A, Meire HB: Real-time ultrasound. A new method of studying gallbladder kinetics. *Br J Radiol 52:*801–803, 1979
26. Martinez A, Velasco M, Caceres J: Usefulness of ceruletide as an aid in the ultrasonographic study of the gallbladder and bile ducts. Preliminary study of 30 cases. *Radiología 26:*203–208, 1984

Received: December 24, 1985; accepted: February 6, 1986