Power Versus Conventional Color Doppler Sonographic Diagnosis Of Acute Cholecystitis: Comparison In The Depiction Of Mural Flow

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ABSTRACT

Background: Gray-scale sonography is generally considered as a first-line diagnostic tool for patient with suspected acute cholecystitis. It is suggested by gallstones, Murphy's sign, thickening of the gallbladder wall and bile sludging, but the specificity of these sonographic findings are not as high as their sensitivity. Blood flow of the gallbladder wall is increased in acute inflammation.

Objective: To evaluate the sensitivity and specificity of power Doppler sonography and compared with conventional color Doppler and gray-scale sonography in diagnosing patients with acute cholecystitis.

Type of the study: This was a cross sectional study.

Patients and methods: The study was conducted through the period from August 2014 to August 2015 on 80 patients with acute right upper quadrant abdominal pain and clinically suspected acute cholecystitis. Firstly, gray-scale sonography of the abdomen was performed. Next, color Doppler and power Doppler sonography of the gallblader wall was done to detect mural flow. Quantifying intramural vascularity was performed using Uggowitzer scoring system. Grading of vascularity ++ and +++ were suggestive of acute cholecystitis. Results of gray-scale and Doppler sonography were compared with post cholecystectomy histopathological results.

Results: The overall sensitivity of gray-scale sonography was 83% while the specificity ranges from 43% for the presence of calculi to 100% for the presence of pericholecystic fluid. Sensitivity of color Doppler sonography for acute cholecystitis was 21%, with a specificity of 86%. Sensitivity of power Doppler sonography for acute cholecystitis was 94%, with a lower specificity 72%.

Conclusion: Power Doppler sonography adds a significant amount of specificity to gray-scale sonography and sensitivity to conventional color Doppler sonography and may further improve confidence in diagnosing acute cholecystitis.

Key words: Acute cholecystitis; power Doppler sonography; vascularity

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Acute cholecystitis is one of the most common reasons for hospital admission in patients with acute abdominal pain. It is a severe disease with high morbidity and significant mortality when untreated or misdiagnosed because of gallbladder rupture, abscesses or peritonitis [1-3]. Sonography has proven to be a sensitive imaging technique in detecting acute cholecystitis [4, 5]. When considering certain sonographic features such as gallbladder wall thickening, the presence of calculi, and the sonographic Murphy's sign; the sensitivity of sonography exceeds 90% [6]. On the other hand, these sonographic signs are not specific because they may also be encountered in chronic cholecystitis and in extrinsic diseases such as pancreatitis, cirrhosis, hepatitis, and congestive heart failure. Biliary calculi may also be noted incidentally in asymptomatic individuals [7-10]. The GB wall is thickened and the vascularisation is increased in acute cholecystitis, but in the chronic cholecystitis the thickening of the GB wall is caused by fibrosis. This pathologic difference is to key point of distinguishing between acute and chronic cholecystitis [11]. Determining the vascularisation of the GB wall with Doppler sonography was showed valuable diagnostic benefits and improvement in the specificity of sonographic diagnosis of acute inflammation [12-14]. Although in histologic sections of acute cholecystitis enlarged arterial vessels and extensive venous filling with extravasation of blood intramurally are evident, no significant improvement of diagnostic reliance could be established with conventional color Doppler sonography [12, 15]. A proposed explanation for these poor results is that blood flow within the gallbladder wall may be below the threshold of detection with conventional color Doppler techniques [16]. However, the current application of power Doppler sonography, which is based on the integrated power of the Doppler frequency spectrum instead of the mean Doppler frequency shifts as in conventional color Doppler sonography, suggests a significant improvement in blood flow detection and visualization of vascular abnormalities [17, 18]. Power Doppler has shown several advantages over color Doppler, including higher sensitivity to flow, better edge definition, and depiction of continuity of flow without aliasing [19, 20].

Accordingly, I undertook this cross sectional study in order to determine the sensitivity and specificity of power Doppler sonography compared with conventional color Doppler and gray-scale sonography in diagnosing acute cholecystitis.

Patients and methods: During a period of 13 months (August 2014 through August 2015), I studied 84 consecutive patients who were referred from the surgical department to the ultrasound division at Al-kindy teaching hospital because of acute right upper quadrant pain and clinically suspected acute cholecystitis. All these patients underwent gray-scale sonography of the gallbladder. From this initial group, four patients were excluded from the study because their inability to hold their breath prevented adequate color examination. The remaining 80 patients (54 women and 26 men who were 20-76 years old; mean age, 52 years old) underwent conventional color Doppler and power Doppler sonography of the gallbladder prospectively using high-resolution sonographic equipment (HD11 XE, Philips) with a 2.5- to 5.0-MHz multifrequency vector array transducer. For the elimination of inter-operator changes, all patients were examined by a single radiologist following a fasting period of a minimum of 6 hours. The examination was routinely performed with longitudinal and transverse scans in the supine and left lateral decubitus positions during suspended respiration. On gray-scale sonographic examinations, the gallbladder wall thickness was measured in the anterior portion of the gallbladder wall in both transverse and sagittal planes. The gallblader wall was considered thickened when it was more than 3 mm. Pericholecystic fluid was considered present when fluid surrounding the gallbladder was seen. Sonographic Murphy's sign was considered positive when maximal tenderness over the sonographically localized gallbladder was noted. The lumen of the gallbladder was also evaluated for the presence of intramural gas and stones.

Both the hepatic and the peritoneal surfaces of the gallbladder wall were assessed for vascularity by conventional color Doppler and power Doppler examinations. To prevent power Doppler sonographic results from interfering with interpretations of conventional color Doppler sonography, power Doppler examinations were performed last. To avoid false-positive findings in color imaging and power Doppler studies due to motion of an echogenic interface that may simulate blood flow, spectral Doppler waveforms were obtained to document arterial flow. In both the color and power Doppler modes, the overall gain was set as high as possible until significant noise began to appear. The color speed scale was decreased as much as possible to optimize visualization of low-velocity and low-flow states. In the power Doppler mode, pulse repetition frequency was adjusted to reduce interfering motion artefacts. To quantify intramural vascularity, the scoring system already described by Uggowitzer et al. [21] was applied. Vascularity was called 0 if no vessel within the gallbladder wall could be identified and + when only solitary or spotty signals (no more than two signals per centimeter) were detected within the wall layer. Multiple scattered signals were assigned a vascularity grade of ++, and a "blush" of the wall or continuously depicted vessels for a length of at least 25 mm were assigned a grade of +++. The resistive index (RI) of the cystic artery was not evaluated in this study because previous studies shows lack of usefulness of measurment of this parameter in the diagnosis of acute cholecystitis [15, 21].

Results of gray-scale and Doppler sonography were compared with histologic findings when cholecystectomy was performed within 5 days. The mean time interval between sonographic examination and surgery with histopathologic evaluation was 2 days. All histologic specimens were reviewed for consistency by a senior staff pathologist.

For patients who did not undergo cholecystectomy, gallbladder disease was excluded on the bases of the results of clinical, biological, and imaging examinations.

Statistical analysis: Statistics of variables and collected data were organized and presented as percentages of sensitivity, specificity, and predictive values which typically considered characteristics of the test itself with corresponding confidence intervals at 95% level. The results were presented in tables with a short discussion for each table.

The ethical and Scientific consideration: Approvals of the local ethical and scientific committees were obtained before study-onset.

Results: In the 80 patients who included in this study, acute cholecystitis was proven histologically in 66. In two cases, extensive transmural necroses and intramural hemorrhage were diagnostic for acute gangrenous cholecystitis. In the remaining 14 patients, various other diseases were diagnosed either clinically (acute renal colic, n = 2; hepatitis, n = 1; acute pneumonia, n = 1; liver abscess, n = 1; congestive heart failure, n = 1; duodenal ulcer, n = 1) or with CT (pancreatitis, n = 1) or were proven histologically (chronic cholecystitis, n = 4; gallbladder carcinoma, n = 2) as probably being responsible for the abdominal symptoms.

In gray-scale sonography, four acknowledged features-the presence of calculi, wall thickness, the sonographic Murphy's sign, and the presence of pericholecystic fluid-were evaluated in establishing the sonographic diagnosis of acute cholecystitis

(Table 1). Sensitivity was highest for the presence of calculi (97%) and the positive sonographic Murphy's sign (94%), whereas sensitivity was markedly lower for wall thickness equal to or greater than 4.5 mm (78%) and the presence of pericholecystic fluid (30%), which, on the other hand, turned out as a highly specific feature (100%) as it was not seen in patients with other diseases. Specificity diminished gradually: 71% for a positive Murphy's sign, 66% for a thickened gallbladder wall, and 43% for the presence of calculi (Table 2). With power Doppler sonography, 62 (94%) of 66 patients suffering from acute cholecystitis had moderate (++) or marked (+++) hypervascularity compared with a significantly lower sensitivity of only 21% (14/66 patients) when using conventional color Doppler sonography (Tables 3 - 6). In the two patients suffering from acute necrotizing cholecystitis, marked hyperemia (+++) was seen on power Doppler sonography, whereas either no (0) or mild (+) vascularity was seen on conventional color Doppler sonography. Conversely, in four patients with histologically proven acute cholecystitis, only a few intramural Doppler signals (score, +) were seen on power Doppler sonography, resulting in a false-negative rate of 6%. However, 49% of patients with acute cholecystitis showed no intramural blood flow on conventional color Doppler sonography (Tables 3 and 4).

In 14 patients (8 women and 6 men), diseases other than acute inflammatory gallbladder disease were diagnosed, including histologically proven chronic cholecystitis. However, in 4 of 14 patients (28%) intramural hypervascularity was present on power Doppler sonography, suggesting acute inflammation (Table 3). Acute pancreatitis was present in one case and a duodenal ulcer in another case, slightly lowering specificity of power Doppler sonography (72%) compared with 86% with conventional color Doppler sonography (Tables 5 and 6). However, in the other two patients, surgery revealed a poorly differentiated diffusely spreading carcinoma of the gallbladder with extensive production of abnormal tumor vessels that appeared hypervascularized in conventional color Doppler sonography and in power Doppler sonography (Tables 3 and 4).

Table 1: Distribution of the study sample according to gray-scale sonographic findings.

Finding	Patients with acute cholecystitis n=66	Patients with other disease n=14
Calculi	64 (97)	8 (57)
Sonographic Murphy's sign	62 (94)	4 (29)
Pericholecystic fluid	20 (30)	0 (0)
Gallbladder Wall thickness (mean ± SD)	5.3 ± 2 mm	5.6 ± 3 mm

Note.-Values in parentheses are percentages.

Table 2: Index values of gray- scale sonographic findings for acute cholecystitis.

Finding	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
Calculi	97 (91 to 99)	43 (33 to 53)	63 (54 to 70)	93 (82 to 98)
Sonographic Murphy's sign	94 (87 to 97)	71 (61 to 79)	76 (68 to 83)	92 (84 to 97)
Pericholecystic fluid	30 (22 to 40)	100 (96 to 100)	100 (88 to 100)	58 (51 to 66)
Wall thickness > 3mm	78 (69 to 82)	66 (56 to 74)	69 (60 to 74)	82 (74 to 89)

Note - All values are percentages. PPV = positive predictive value, NPV = negative predictive value, CI = confidence interval.

Table 3: Distribution of the study sample according to score finding on power Doppler Sonography results.

Score	Patients with acute cholecystitis n=66 (%)	Patients with other diseases n=14 (%)
0	0 (0)	6 (43)
+	4 (6)	4 (29)
++	28 (42)	2[a] (14)
+++	34 (52)	2[b] (14)

a duodenal ulcer, acute pancreatitis **b** gallbladder carcinoma

Table 4: Distribution of the study sample according to score finding on conventional color Doppler sonography results.

Score	Patients with acute cholecystitis n=66(%)	Patients with other diseases n=14(%)
0	32 (49)	8 (57)
+	20 (30)	4 (29)
++	10 (15)	0 (0)
+++	4 (6)	2[a] (14)

a gallbladder carcinoma

Table 5: Index values of power Doppler sonographic findings for acute cholecystitis.

Statistic	Value	95% CI
Sensitivity	94%	87% to 98%
Specificity	72%	62% to 81%
PPV	77%	69% to 84%
NPV	92%	84% to 97%

Note - PPV = positive predictive value, NPV = negative predictive value, CI = confidence interval

Table 6: Index values of color Doppler sonographic findings for acute cholecystitis.

Statistic	Value	95% CI
Sensitivity	21%	13% to 30%

Specificity	86%	78% to 92%
PPV	60%	42% to 76%
NPV	52%	44% to 60%

Note – PPV = positive predictive value, NPV = negative predictive value, CI = confidence interval

Discussion: Marked variations in the accuracy of gray-scale sonography for diagnosing acute cholecystitis are reported in the radiology literature ranging from 60% to 98% [4-6]. These variations were influenced by the selection of patients, the operator dependency of sonographic examinations, and histopathologic interpretations. Gray-scale sonography has proven to be sensitive in detecting acute cholecystitis [4,5]. This study showed a sensitivity of gray scale sonography of 83% for acute cholecystitis, this is comparable to a study done by Soyer et al. [11] who reported a sensitivity of 86% for diagnosis of acute cholecystitis by gray scale sonography.

Gray-scale sonography is nonspecific in the diagnosis of acute cholecystitis except in cases of the visualization of an obstructing calculus within a hydropic gallbladder [4,7-10]. In this study, patients with a markedly thickened gallbladder wall suffered from acute cholecystitis as well as other diseases such as chronic cholecystitis, congestive heart failure and carcinoma of the gallbladder. Also, the sonographic Murphy's sign was encountered in four patients who suffered not from acute cholecystitis but from gallbladder carcinoma (two cases), duodenal ulcer (one case), and chronic cholecystitis (one case). With the exception of evident pericholecystic fluid, gray-scale sonographic findings lacked sufficient specificity for the diagnosis of acute cholecystitis. In two cases in which gangrenous transmural inflammation of the gallbladder wall was revealed histologically, the sonographic Murphy's sign was either negative or indeterminate, but extensive hyperemia (+++) in the power Doppler mode was diagnostic.

In this study and for the elimination of inter-operator changes, all patients were examined by a single radiologist who applied strictly the guidelines of gain optimization in the power mode. Vascularity scores (+++ and ++) were used synonymously for hypervascularity and for acute cholecystitis to establish criteria constantly used in the study. However, regarding each hypervascular gallbladder wall in a symptomatic patient as acute inflammatory reaction might be the cause for false-positive results because acute cholecystitis was not the primary diagnosis in three patients with hypervascularity in the power Doppler mode. In two patients (one with acute pancreatitis and one with a duodenal ulcer), cholecystitis might have been concomitant but was not confirmed histologically because no surgical intervention was necessary. In the single actual false-positive case, a carcinoma of the gallbladder with diffuse thickening of the gallbladder wall was misinterpreted as acute cholecystitis. However. therapy was not delayed because the Doppler sonography results prompted immediate surgical intervention. Although infrequent and usually hypovascular on Doppler sonography, malignancies of the gallbladder may sometimes be the cause of intramural hyperemia in Doppler sonography being indistinguishable from acute inflammation. Assessment of spectral waveforms was mandatory to identify true blood flow instead of signals resulting from motion artifacts. Power Doppler sonography is a sensitive method for detecting hyperemia within the gallbladder wall. In contrast to conventional color Doppler sonography and because of a different physical signal-encoding process, the signal-to-noise ratio in power Doppler sonography is improved significantly, thus increasing sensitivity of flow detection even without wall thickening in acutely inflamed and distended gallbladder.

Results of this study were in agreement with Uggowitzer et al. [21] who reported a sensitivity of 95% and specificity of 86% for power Doppler and sensitivity of 33% and specificity of 95% for color Doppler for diagnosing acute cholecystitis.

This study and other prior studies [13, 15, 16] showed that conventional color Doppler sonography was not sensitive enough to exclude the diagnosis of acute cholecystitis and this disagree with Soyer et al. [11] who reported a high sensitivity of color velocity imaging reaching 95% for diagnosing of acute cholystitis. These disappointing results in terms of sensitivity might have been due to an insufficient threshold of detection with conventional color Doppler compared with color velocity imaging techniques [17]. Also some studies [17, 22] proved that color velocity imaging have increased sensitivity compared with conventional color Doppler sonography which is based on the mean Doppler frequency shift.

Finally, the results of this study could be affected by technical considerations. Although I used the most sensitive color Doppler settings possible, an inherent limitation of all color Doppler studies is that with technological advances, sensitivity in detecting flow may improve. Also, and because of recent improvements in sonographic technology, most equipment will become more sensitive for power Doppler imaging.

Conclusion: Power Doppler sonography is more sensitive than conventional color doppler and more specific than gray-scale sonography for diagnosing patients with acute cholecystitis. The results of this study suggest that color Dopper and power Doppler sonography should be routinely obtained in patients with suspected acute cholecystitis to improve the diagnostic value of gray-scale sonography.

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