ORIGINAL ARTICLE

Ultrasound Diagnosis of Cholecystitis and Cholelithiasis: A Study of Various Types and Complications for Better Management

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Abstract

Introduction: Ultrasound examination plays a crucial role in diagnosing cholecystitis and cholelithiasis, but its reliability in predicting inflammation severity and distinguishing between acute and chronic cholecystitis remains contested. This study aimed to provide ultrasound examination of various types of cholecystitis and cholelithiasis. **Materials and Methods:** A total of 650 subjects, including 48 healthy controls and 602 patients who underwent surgery for acute, chronic, destructive cholecystitis, or cholelithiasis, were examined using a Siemens scanner. Ultrasonography parameters assessed blood flow in the branches and veins of the cystic artery using color Doppler scanning and pulsed-wave Doppler. Quantitative blood flow velocity indicators and angle-independent total peripheral resistance indices were examined. **Results:** Gallbladder length and area were significantly increased in acute, phlegmonous, and gangrenous inflammation compared to controls. Wall thickness exceeded 4–5 mm in acute and phlegmonous-gangrenous inflammation. Maximum systolic blood flow velocity in the cystic artery more than doubled in acute, phlegmonous, and gangrenous inflammation, while minimum systolic velocity showed no significant changes. Total peripheral resistance indices increased in chronic, phlegmonous, and gangrenous inflammation but remained within control values in acute inflammation. The control group showed no significant differences in ultrasonographic indicators across all age groups. **Conclusion:** These findings highlight the importance of comprehensive clinical assessment alongside ultrasound imaging for accurate diagnosis and management of cholecystitis and cholelithiasis.

Key words: Blood flow, cholecystitis, cholelithiasis, Doppler, gallstones, inflammation, ultrasound

INTRODUCTION

Around 15% of adults in affluent nations experience inflammatory and degenerative gallbladder disorders.[1] Cholecystitis predominantly leads to gallstones composed mainly of calcium ions, bilirubin, lipids, and other minor components.[2] Cholelithiasis or gallstone disease leads to the formation of gallstones. These stones were categorized based on their cholesterol content into cholesterol stones, mixed stones, or pigment stones.[3]

Ultrasound examination of cholecystitis and cholelithiasis can reveal various findings associated with the different stages and complications. Common indicators of cholecystitis include gallstones, gallbladder wall thickening, and pericholecystic fluid.[4,5] The sonographic murphy sign, elicited when maximal tenderness is noted over the gallbladder during ultrasonography, is associated with acute cholecystitis, although its moderate specificity can result in false positives.[4]

However, the reliability of certain sonographic features for predicting inflammation severity or distinguishing between acute and chronic cholecystitis has been contested. Gallbladder wall thickening, although common, does not correlate well with the pathological severity of inflammation.[6] No single

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sonographic feature is sufficiently sensitive or specific to definitively diagnose complicated cholecystitis.[7]

Thus, while ultrasound imaging is crucial for diagnosing cholecystitis and cholelithiasis, with gallstones being a key feature,[5] the variability in sonographic presentations and limitations in specificity and sensitivity necessitates comprehensive clinical assessment for accurate diagnosis and management.[4,6,7]

Further exploration of ultrasound indicators of cholecystitis and identifying criteria to predict complications arises from the crucial role of ultrasound in diagnosis and treatment planning. Current information on the Doppler characteristics of venous blood flow in the gallbladder wall during acute cholecystitis is sparse, as is data on hemodynamic changes in the gallbladder vessels during chronic inflammation.

In addition, there is limited research on the Doppler parameters of blood flow in cases of complicated cholecystitis. These gaps in the ultrasound diagnosis of cholecystitis variants underlie this study. The aim of this study was to provide ultrasound examination of various types of cholecystitis and cholelithiasis.

MATERIALS AND METHODS

A total of 650 subjects, ranging in age from 19 to 78 years, comprised the control and clinical groups. Among these, 48 healthy individuals formed the control group, whereas the clinical group included 602 patients who had undergone surgery for acute, chronic, destructive cholecystitis, or cholelithiasis. Interestingly, women dominated both groups, representing 80.6% of the clinical group and 64% of the control group, respectively.

Following the surgical diagnosis of gallbladder pathology, we observed that 425 patients had acute and chronic calculous cholecystitis, 39 had acute and chronic calculous gangrenous cholecystitis, 94 had acute calculous cholecystitis, and 144 had chronic calculous cholecystitis. Notably, destructive forms of cholecystitis were identified in most patients (464), with phlegmonous inflammation being the most prevalent form of inflammation.

Ultrasound was conducted using an ACUSON Sequoia color Doppler ultrasound system (Siemens, Germany). A 10L4 linear array probe, functioning at 3.5–7.5 MHz and measuring 0.5–10.0 m/s, was utilized. Experienced radiologists, each with over 5 years in abdominal ultrasonography, conducted standard ultrasound. Emergency examinations were conducted without any special preparation, whereas planned examinations were performed strictly on an empty stomach. During the study, the presence of gallstones, their size, degree of inflammation, thickness of the gallbladder wall, size of the gallbladder, diameter of the common bile and hepatic ducts, presence and mobility of stones, and size and structure of the liver and pancreas were assessed, and the diameter of the pancreatic duct was measured.

Ultrasonography parameters assessed the blood flow in the branches and veins of the cystic artery. Color Doppler scanning and color Doppler mapping with pulsed-wave Doppler were used to evaluate the blood supply to the gallbladder wall. Standard quantitative blood flow velocity indicators, such as peak systolic velocity (V_{max}), and end-diastolic velocity (V_{min}), were examined, along with angle-independent total peripheral resistance indices, such as the pulsatility and resistance indices (PI, RI).

These indices were calculated as $RI = \frac{(Vmax - Vmin)}{Vmax}$ and

$$PI = \frac{(Vmax - Vmin)}{Vmin}$$

Doppler settings included a 100 filter, pulse repetition frequency of 1.0–4.5 kHz, and a 1 mm control volume. The pulsed-wave Doppler spectrum showed arterial blood flow, and quantitative indicators such as V_{max} (peak systolic velocity on the echogram) and V_{min} (end-diastolic velocity on the echogram, RI < PI) were determined. This study adhered to the declaration of Helsinki, 2013 and was approved by the Bioethical Committee of the International Higher School of Medicine (Protocol No. 24, dated February 24, 2023).

Statistical analyses were performed using Statistical Packages for the Social Sciences version 11.5. Results are expressed as the mean ± standard deviation and n (%). Differences were considered statistically significant at $P < 0.05$, $P < 0.01$, and $P < 0.001$ compared with the control.

RESULTS

Table 1 indicates that the gallbladder ultrasound results in the control group exhibited no significant differences ($P > 0.05$) in ultrasonographic indicators across all age groups [Table 1]. This suggests the stability of both morphological and functional values of the biliary system during aging in humans. Therefore, the mean ultrasound values for the control group were calculated for all patients for comparison with those of the clinical group.

Comparison of the ultrasound results of the gallbladder between patients and the control group [Table 2] revealed distinct ultrasonographic signs of various types of inflammation. Gallbladder length was significantly increased in acute, phlegmonous, and gangrenous inflammation ($P < 0.05$). The gallbladder area also expanded in gangrenous (84.5 ± 9.6 mL) and phlegmonous inflammation (91.2 ± 8.2 mL) ($P < 0.001$). Acute inflammation showed an area of 66.4 ± 11.7 mL ($P < 0.01$), and chronic inflammation was 36.1 ± 8.3 mL ($P < 0.05$). The wall thickness significantly exceeded the control values, measuring over 4–5 mm in acute and phlegmonous-gangrenous inflammation ($P < 0.001$).

V_{max} in the cystic artery more than doubled compared to non-inflamed gallbladders, reaching 27.1 ± 4.9 cm/s in acute inflammation and 28.6 ± 3.0 cm/s in phlegmonous and 29.2 ± 2.7 cm/s in gangrenous inflammation ($P < 0.01$). However, the minimum systolic velocity showed no significant changes across all inflammation types ($P > 0.05$). The total RI and PI increased in chronic, phlegmonous, and gangrenous inflammation ($P < 0.05$–$P < 0.01$), while acute inflammation remained within the control values ($P > 0.05$).

Ultrasound findings indicated that gallbladder stones were mostly within the range of 10 mm or less (82%), and in most cases, multiple stones were present (81%). The hepaticocholedochus diameters were as follows: 33.6%, <8 mm; 10.3% measured 8–10 mm, 45.1% measured 11–20 mm, 7.9% measured 20–25 mm, 3.9%, >25 mm.

Table 1: The quantitative values of gallbladder size and blood flow for individuals in the control group were categorized by age

Options	Age categories (years)		
	19–44	45–60	>61
Length (A) (mm)	70.1±8.5	65.3±10.5	66±12.1
Width (B) (mm)	23.8±6.5	25.3±7.0	28.5±7.7
Ratio (A/B)	3.4±0.6	3.1±0.5	2.8±0.4
Area (cm^3)	11.2±4.8	13.9±4.9	13.7±5.0
Volume (mL)	14.0±6.0	18.9±5.7	18.6±4.4
Wall thickness (mm)	1.92±0.4	2.0±0.5	2.6±0.4
V_{max} (cm/s)	14.5±2.0	11.1±1.8	10.3±2.1
V_{min} (cm/s)	6.8±1.9	5.4±1.2	4.9±2.7
Resistance index	0.64±0.05	0.62±0.04	0.62±0.06
Pulsatility index	1.5±0.2	1.4±0.19	1.5±0.3

*P<0.05, **P<0.01, ***P<0.001. Values are presented as the M±m=mean±SD. V_{max}: Peak systolic velocity, V_{min}: End-diastolic velocity, SD: Standard deviation

In most cases (66.6%), there were multiple stones in the hepaticocholedochus, and in 68.3% of cases, the stone size did not exceed 10 mm. The intrahepatic ducts were predominantly non-dilated (89.3%).

The gallbladder showed signs of destructive cholecystitis, including an increase in size and the presence of stagnant contents and echo-structures that produced acoustic shadows. In addition, significant signs included the degree of thickening of the gallbladder wall, the presence of dissections, and clarity of contours. Acute cholecystitis without signs of destruction of the gallbladder wall is characterized by an increase in gallbladder size with the visualization of heterogeneous contents ("suspension").

The gallbladder wall was homogeneous with an even contour and thickened. In chronic cholecystitis, mild thickening of the gallbladder wall and uneven wall contours are observed in the presence of an acoustic shadow in the gallbladder lumen. In the phlegmonous form of inflammation, blurred contours of the gallbladder wall and more pronounced thickening of the wall with the characteristic symptom of "doubling its contours." The gangrenous form of inflammation is characterized by an increase in gallbladder size, blurred contours, and pronounced thickening of the gallbladder wall with wall fragmentation and replaced fluid formation.

Ultrasound failures were mainly associated with the presence in patients of excess subcutaneous fat, significant flatulence, and pronounced adhesions in the abdominal cavity due to previous surgery.

DISCUSSION

Ultrasound is essential for diagnosing and distinguishing cholecystitis from cholelithiasis. Cholelithiasis, marked by gallstones, is reliably detected through ultrasonography due to its high sensitivity and specificity.[8] Typical ultrasound

Table 2: Ultrasonographic indicators of the gallbladder during inflammation in patients

Indicators	Variants of inflammation of the gallbladder				
	No signs	Acute	Chronic	Phlegmonous	Gangrenous
Length (A) (mm)	67.4±9.5	92.4±12.9*	69.2±5.9	100.1±14.1*	97.5±8.9
Width (B) (mm)	26.1±6.8	37.0±8.5	29.2±5.2	38.0±6.8	37.7±5.3
Ratio (A/B)	3.15±0.34	2.7±0.5	2.2±0.25*	2.82±0.31	2.6±0.44
Square (cm^3)	12.6±5.1	28.7±4.5*	16.0±5.2	30.5±4.7*	31.3±4.2*
Volume (mL)	16.7±5.3	66.4±11.7**	36.1±8.3*	84.5±9.6***	91.2±8.2***
Thickness (mm)	1.98±0.45	4.5±0.1***	2.59±0.35	5.6±0.4***	5.2±0.37***
V_{max} (cm/s)	12.7±1.5	27.1±4.9**	16.8±2.4	28.6±3.2**	29.2±2.7**
V_{min} (cm/s)	5.9±1.2	6.0±1.2	6.79±1.3	7.8±1.0	7.9±0.95
Resistance index	0.63±0.04	0.64±0.03	0.71±0.02*	0.74±0.03*	0.77±0.035*
Pulsatility index	1.47±0.02	1.5±0.05	3.8±0.18***	2.2±0.04*	2.7±0.03*

*P<0.05, **P<0.01, ***P<0.001. Values are presented as the ±m=mean±SD. V_{max}: Peak systolic velocity, V_{min}: End-diastolic velocity, SD: Standard deviation

findings for gallstones include a reflective echo with posterior acoustic shadowing and mobility on patient repositioning.[8]

However, gallstones alone do not confirm acute cholecystitis. Additional ultrasound indicators such as gallbladder distension, wall edema, and pericholecystic fluid suggest acute cholecystitis.[9] The diagnostic accuracy of ultrasound for acute cholecystitis increases when multiple signs are observed.[9] Surgeon-performed ultrasound is equally effective as that performed by radiologists for diagnosing acute cholecystitis.[10] Specific sonographic variables such as gallbladder distension, wall abnormalities, and elevated common hepatic artery peak systolic velocity are particularly predictive of acute cholecystitis.[11] Elevated peak systolic hepatic arterial velocity is also a useful diagnostic parameter.[12]

Thus, ultrasound is highly effective for detecting cholelithiasis and differentiating between acute and chronic cholecystitis. While identifying gallstones is straightforward, diagnosing acute cholecystitis requires additional sonographic signs and specific predictive variables.[8,9,11,12]

Ultrasound accurately diagnoses cholelithiasis and cholecystitis even when oral cholecystography results are normal.[13] Surgeon-performed ultrasonography effectively diagnoses acute cholecystitis in cholelithiasis patients, with accuracy comparable to that of radiologist-performed ultrasonography.[10]

However, differentiating between cholecystitis and cholelithiasis can be complicated by pericholecystic adhesions, which pose challenges during laparoscopic cholecystectomy.[14] Endoscopic ultrasonography can accurately diagnose gallbladder wall lesions regardless of gallstones, suggesting that refined ultrasound technology can improve the diagnostic accuracy for gallbladder diseases.[15]

With ongoing technological advancements that promise increased precision in identifying and differentiating gallbladder conditions, ultrasound imaging reliably diagnoses cholelithiasis and cholecystitis.

CONCLUSION

Ultrasound scans of destructive cholecystitis showed an enlarged gallbladder, stagnant contents, and acoustic shadows along with thickening and dissection of the gallbladder wall. Systolic blood flow velocity in the cystic artery was twice the normal rate. Stones were presented, mostly up to 10 mm in size, and with varying dimensions.

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