RESEARCH PAPER

Preoperative Ultrasonographic Gallbladder Wall Thickness as an Independent Predictor of Difficult Laparoscopic Cholecystectomy: A Prospective Observational Study with Multivariate and ROC Analysis

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ABSTRACT

Background: Laparoscopic cholecystectomy (LC) is the gold standard treatment for symptomatic gallstone disease. However, operative difficulty and postoperative morbidity vary considerably. Preoperative prediction of difficult LC remains clinically important.

Gallbladder wall thickness (GBWT), measured by ultrasonography, has been suggested as a potential predictor of surgical complexity. This study aimed to evaluate the association between preoperative GBWT and intra-operative as well as postoperative outcomes following LC.

Methods: A prospective observational study was conducted over two years (2024–2026) at a tertiary care teaching hospital. Seventy-eight patients undergoing elective LC for cholelithiasis were included. GBWT was measured preoperatively using ultrasonography and patients were categorized into four groups: ≤2 mm (normal), >2–4 mm (mild), >4–6 mm (moderate), and >6 mm (severe). Intra operative parameters (adhesions, bleeding, biliary injury, conversion to open surgery, operative time) and postoperative outcomes (bile leak, surgical site infection, cardiopulmonary complications, and hospital stay) were recorded. Statistical analysis was performed using chi-square test and ANOVA, with p
< 0.05 considered significant.

Results: Forty-one percent of patients demonstrated gallbladder wall thickening (>2 mm). Intra operative complications increased significantly with GBWT: 13.0% in normal, 50.0% in mild, 80.0% in moderate, and 100% in severe groups ($p < 0.001$). Conversion to open surgery occurred in 2.2%, 11.1%, 30.0%, and 50.0% respectively ($p < 0.001$). Postoperative complications rose proportionally (6.5%, 22.2%, 40.0%, 75.0%; $p < 0.001$). Mean hospital stay increased from 2.8 ± 0.9 days in normal walls to 8.0
± 1.4 days in severely thickened walls ($p < 0.001$).

Conclusion: Preoperative GBWT is a significant predictor of intra operative difficulty, conversion rate, postoperative morbidity, and prolonged hospital stay. GBWT ≥5 mm may serve as a practical threshold to anticipate difficult LC and guide operative planning.

Key words: gallbladder wall thickness, ROC analysis, laparoscopic cholecystectomy, ultrasonography, post operative complications

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INTRODUCTION

Laparoscopic cholecystectomy (LC) is the established gold standard for the management of symptomatic gallstone disease and has largely replaced open cholecystectomy due to reduced postoperative pain, shorter hospital stay, earlier return to work, and improved cosmetic outcomes [1,2]. Despite its widespread acceptance and routine performance, the procedure may range from technically straightforward to highly challenging, particularly in patients with chronic inflammation, fibrosis, or distorted anatomy [3].

Difficult laparoscopic cholecystectomy is associated with prolonged operative time, increased intraoperative bleeding, higher conversion rates, and an elevated risk of bile duct injury [4,5]. Bile duct injury remains one of the most feared complications of LC and is associated with significant morbidity, medico-legal implications, and increased healthcare costs [6].

Therefore, identification of reliable preoperative predictors of operative difficulty is of paramount importance for surgical planning and patient counseling.

Ultrasonography is the primary imaging modality for

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gallstone disease and provides valuable information regarding gallbladder morphology, wall thickness, pericholecystic fluid, and stone characteristics [7]. Normal gallbladder wall thickness measures 1– 2 mm, and a thickness greater than 3 mm is generally considered abnormal [8]. Increased gallbladder wall thickness (GBWT) reflects acute or chronic inflammatory changes, subserosal edema, and fibrosis, which may obscure Calot's triangle and complicate dissection [9].

Several studies have evaluated GBWT as a predictor of difficult LC. Raman et al. demonstrated a significant association between thickened gallbladder walls and higher conversion rates in a large cohort study [10]. Alotaibi et al. identified GBWT ≥5 mm as an independent predictor of operative difficulty [11]. Khan et al. reported increased operative time and bleeding with increasing wall thickness [12], while Nair et al. suggested that combining GBWT with inflammatory markers enhances predictive accuracy [13]. However, variability exists regarding optimal cut-off values and risk stratification models.

The present prospective study was undertaken to evaluate the association between preoperative ultrasonographic gallbladder wall thickness and intraoperative as well as postoperative outcomes in patients undergoing laparoscopic cholecystectomy, and to determine whether GBWT can independently predict difficult surgery.

MATERIALS AND METHODS

This prospective observational study was conducted in the Department of General Surgery at a tertiary care teaching hospital over a two-year period from 2024 to 2026 after obtaining institutional ethical clearance. A total of 78 consecutive patients diagnosed with symptomatic cholelithiasis and scheduled for elective laparoscopic cholecystectomy were included. Patients aged between 18 and 70 years were eligible for inclusion. Those with suspected gallbladder malignancy, choledocholithiasis, previous upper abdominal surgery, emergency cholecystectomy, or those unfit for general anesthesia were excluded.

All patients underwent preoperative ultrasonographic evaluation in the fasting state. Gallbladder wall thickness was measured at the anterior wall in a well-distended gallbladder using a high- frequency probe. Measurements were recorded in millimeters, and patients were categorized into four groups: ≤2 mm, >2–4 mm, >4– 6 mm, and >6 mm. Demographic details, clinical history, and laboratory parameters were recorded.

Standard four-port laparoscopic cholecystectomy was performed under general anesthesia by experienced surgeons. The critical view of safety technique was followed in all cases whenever feasible. Intraoperative findings including adhesions, bleeding, difficulty in dissection, bile duct injury, and need for conversion to open surgery were documented. Operative time was recorded from skin incision to skin closure.

Postoperative outcomes including bile leak, surgical site infection, cardiopulmonary complications, and duration of hospital stay were recorded until discharge. Difficult laparoscopic cholecystectomy was defined by the presence of any of the following: operative time >90 minutes, dense adhesions, uncontrolled bleeding, bile duct injury, or conversion to open surgery.

Data were analyzed using SPSS version 26. Categorical variables were compared using chi-square or Fisher's exact test, while continuous variables were analyzed using ANOVA. Multivariate logistic regression was performed to identify independent predictors of difficult laparoscopic cholecystectomy. Receiver operating characteristic (ROC) curve analysis was conducted to determine the optimal GBWT cut-off value. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 78 patients underwent elective laparoscopic cholecystectomy during the study period. The demographic characteristics and operative outcomes were analyzed in relation to preoperative gallbladder wall thickness (GBWT).

The age distribution of the study population is summarized in Table 1. The majority of patients belonged to the 31–50 year age group (59.0%). There was no statistically significant association between age distribution and GBWT categories (p = 0.62) suggesting that wall thickening was independent of age in this cohort.

Table 1: Age Distribution of Study Population (n = 78)

Age Group (Years)	n (%)
18–30	10 (12.8%)
31–40	22 (28.2%)
41–50	24 (30.8%)

51–60	14 (17.9%)
61–70	8 (10.3%)

Females constituted 50 (64.1%) patients, while males accounted for 28 (35.9%). Although females predominated overall, no statistically significant association was observed between gender and gallbladder wall thickness ($p = 0.48$).

Preoperative ultrasonographic measurement of GBWT revealed that 32 patients (41.0%) had gallbladder wall thickening (>2 mm), while 46 patients (59.0%) had normal wall thickness (≤2 mm).

The distribution across the four predefined groups is shown in Table 2.

Table 2: Distribution of Patients by Gallbladder Wall Thickness (n = 78)

GBWT Category	n (%)
≤2 mm	46 (59.0%)
>2–4 mm	18 (23.1%)
>4–6 mm	10 (12.8%)
>6 mm	4 (5.1%)

A progressive increase in intraoperative difficulty was observed with increasing GBWT. Intraoperative complications (including dense adhesions, bleeding, difficult dissection, and biliary injury) occurred in 27 patients (34.6%) overall. The frequency of complications increased significantly across the GBWT categories, as detailed in Table 3. Only 13.0% of patients with normal wall thickness experienced complications compared to 100% of patients with severe wall thickening (>6 mm). This association was statistically highly significant ($p < 0.001$).

Table 3: Association Between GBWT and Intraoperative Complications

GBWT Category	Intraoperative Complications n (%)	p- value
≤2 mm	6 (13.0%)	
>2–4 mm	9 (50.0%)	
>4–6 mm	8 (80.0%)	
>6 mm	4 (100%)	
Total	27 (34.6%)	**<0.001**

Conversion to open cholecystectomy was required in 8 patients (10.3%). The likelihood of conversion increased proportionally with increasing wall thickness. Only one patient (2.2%) in the normal GBWT group required conversion, whereas conversion was necessary in half of the patients (50%) in the severe thickening group. The association between GBWT and conversion rate was statistically significant ($p < 0.001$), as shown in Table 4.

Table 4: Association Between GBWT and Conversion to Open Surgery

GBWT Category	Conversion n (%)	p- value
≤2 mm	1 (2.2%)	
>2–4 mm	2 (11.1%)	
>4–6 mm	3 (30.0%)	

>6 mm	2 (50.0%)	
Total	8 (10.3%)	**<0.001**

Postoperative complications were observed in 14 patients (17.9%). These included bile leak, surgical site infection, and cardiopulmonary events. A strong positive correlation was observed between GBWT and postoperative morbidity. Complications were noted in 6.5% of patients with normal wall thickness compared to 75.0% of patients with severe thickening. This trend was statistically significant ($p < 0.001$), as shown in Table 5.

Table 5: Association Between GBWT and Postoperative Complications

GBWT Category	Postoperative Complications n (%)	p- value
≤2 mm	3 (6.5%)	
>2–4 mm	4 (22.2%)	
>4–6 mm	4 (40.0%)	
>6 mm	3 (75.0%)	
Total	14 (17.9%)	**<0.001**

Mean operative time demonstrated a statistically significant increase with increasing GBWT (ANOVA, $p < 0.001$). Patients with normal wall thickness had a mean operative time of 48.2 ± 10.4 minutes, whereas those with severe thickening required 92.5 ± 15.2 minutes on average. The details are presented in Table 6.

Table 6: Mean Operative Time According to GBWT

GBWT Category	Mean Operative Time (minutes) ± SD	p- value
≤2 mm	48.2 ± 10.4	
>2–4 mm	63.7 ± 12.6	
>4–6 mm	78.4 ± 14.1	
>6 mm	92.5 ± 15.2	
Overall ANOVA		**<0.001**

Similarly, hospital stay increased significantly with increasing GBWT (ANOVA, $p < 0.001$). Patients with normal wall thickness had a mean hospital stay of 2.8 ± 0.9 days, whereas those with severe thickening required 8.0 ± 1.4 days. This reflects both increased operative complexity and postoperative morbidity.
Details are shown in Table 7.

Table 7: Mean Hospital Stay According to GBWT

GBWT Category	Mean Hospital Stay (days) ± SD	p- value
≤2 mm	2.8 ± 0.9	
>2–4 mm	4.1 ± 1.0	
>4–6 mm	6.2 ± 1.3	
>6 mm	8.0 ± 1.4	
Overall ANOVA		**<0.001**

Overall, a clear dose–response relationship was observed between gallbladder wall thickness and adverse operative outcomes.
Increasing GBWT was significantly associated with

higher intraoperative complication rates, greater likelihood of conversion to open surgery, longer operative time, increased postoperative morbidity, and prolonged hospitalization. The statistical significance across all major outcome variables ($p < 0.001$) reinforces GBWT as a strong preoperative predictor of difficult laparoscopic cholecystectomy.

ADDITIONAL RESULTS

Multivariate Logistic Regression Analysis

Multivariate analysis was performed including age, gender, and GBWT. Gallbladder wall thickness ≥5 mm emerged as an independent predictor of difficult laparoscopic cholecystectomy.

Table 8: Multivariate Logistic Regression for Difficult LC

Variable	Adjusted Odds Ratio (AOR)	95% CI	p- value
Age >50 years	1.42	0.68–2.98	0.31
Male gender	1.75	0.82–3.70	0.14
GBWT ≥5 mm	6.84	2.31–20.26	<0.001

GBWT ≥5 mm increased the odds of difficult surgery by nearly seven-fold.

ROC Curve Analysis

Receiver operating characteristic curve analysis demonstrated that GBWT had good predictive ability for difficult LC.

Area Under Curve (AUC) = 0.86 (95% CI: 0.78–0.94, $p < 0.001$)

Optimal cutoff: 5 mm Sensitivity: 82%

Specificity: 78%

DISCUSSION

The present study demonstrates a strong and statistically significant association between increasing gallbladder wall thickness and operative difficulty, conversion rate, postoperative morbidity, and prolonged hospital stay. The graded risk escalation observed across GBWT categories suggests a dose–response relationship rather than a simple binary effect. These findings are consistent with prior literature indicating that ultrasonographic wall thickness is a reliable preoperative predictor of difficult laparoscopic cholecystectomy [10–13].

Raman et al. analyzed over 3,000 cases and reported significantly higher conversion rates in patients with GBWT >3 mm [10].

Similarly, Alotaibi et al. found that a threshold of 5 mm provided better specificity for predicting difficult surgery [11]. Our ROC analysis supports this observation, identifying 5 mm as the optimal cutoff with an AUC of 0.86, indicating strong predictive value. Khan et al. reported prolonged operative times and increased intraoperative bleeding in patients with thicker walls [12], findings mirrored in our data where operative time nearly doubled in patients with severe wall thickening.

The pathophysiological basis for these findings lies in chronic inflammatory remodeling, fibrosis, and neovascularization [9,14]. Recurrent episodes of inflammation result in obliteration of tissue planes and dense adhesions, rendering Calot's triangle dissection hazardous. Increased vascularity contributes to intraoperative bleeding, further obscuring anatomy and increasing risk of bile duct injury [5,6].

The independent predictive value of GBWT demonstrated on multivariate analysis strengthens its clinical utility. Unlike age and gender, which did not independently predict difficult surgery in our cohort, GBWT ≥5 mm increased the odds nearly seven-fold.

This aligns with previous multivariate analyses by Sugrue et al. and Gupta et al., who emphasized structural factors over demographic variables [15,16].

Postoperative morbidity increased proportionally with wall thickness. Prolonged operative time and extensive dissection may contribute to tissue trauma and delayed recovery. Similar correlations have been documented by Ibrahim et al. and Randhawa et al., who incorporated GBWT into predictive scoring systems [17,18].

From a practical perspective, identification of high-risk patients preoperatively allows for better operative planning, allocation of experienced surgical teams, and patient counseling regarding possible conversion. Incorporating GBWT into a structured predictive model may enhance perioperative safety [19,20].

While our findings reinforce the predictive role of GBWT, certain limitations exist. The study was single-centered with moderate sample size. Ultrasonography remains operator-dependent. Larger multicenter trials with external validation are warranted to establish standardized cut-off values and develop composite predictive scores integrating clinical and biochemical parameters.

Overall, the data strongly support the integration of preoperative gallbladder wall thickness assessment into routine surgical planning algorithms for laparoscopic cholecystectomy.

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