

Gallbladder Wall Vascularity on Doppler Imaging as a Marker of Surgical Difficulty: A Retrospective Study from Darbhanga Medical College & Hospital, Bihar

Neeraj Kumar Rajak¹, Shiva Nand², Srikant Kustwar³

¹Senior Resident, Department of General Surgery, Darbhanga Medical College & Hospital, Darbhanga, Bihar, India

²Associate Professor, Department of General Surgery, Darbhanga Medical College & Hospital, Darbhanga, Bihar, India

³Resident (JR-3), Department of General Surgery, Darbhanga Medical College & Hospital, Darbhanga, Bihar, India

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Corresponding Author: Neeraj Kumar Rajak

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Abstract:

Background/Objectives: Preoperative prediction of surgical difficulty is crucial in laparoscopic cholecystectomy to enhance patient safety and surgical planning. Gallbladder wall vascularity detected on Doppler ultrasonography reflects active inflammation and may serve as an indicator of technical complexity. This study aimed to assess whether increased Doppler vascularity correlates with difficult cholecystectomy and to determine its diagnostic performance as a predictive marker.

Methods: A retrospective study was conducted at DMCH, Bihar, between January 2023 and December 2024. Fifty-two patients who underwent preoperative Doppler ultrasonography and subsequent cholecystectomy were included. Gallbladder wall vascularity was graded from 0 to 3 based on color Doppler flow signals. Intraoperative difficulty was assessed using Nassar's grading system and correlated with vascularity, operative time, blood loss, and conversion rate. Statistical analysis included ROC curve analysis, chi-square test, and Spearman correlation.

Results: Increased vascularity (Grade ≥ 2) showed a strong association with difficult cholecystectomy ($P < 0.01$). Intraoperative blood loss and operative time increased progressively with vascularity grade. The ROC curve demonstrated good predictive accuracy (AUC = 0.73), and a vascularity threshold of Grade ≥ 2 achieved 76% sensitivity and 60% specificity. Low vascularity grades (0–1) were associated with uncomplicated surgeries and shorter operative times.

Conclusion: Gallbladder wall vascularity on Doppler imaging is a simple, reproducible, and cost-effective preoperative marker for predicting difficult cholecystectomy. Incorporating vascularity grading into routine ultrasonography can aid in operative planning and improve surgical safety.

Keywords: Gallbladder Wall Vascularity, Doppler Ultrasonography, Surgical Difficulty, Cholecystectomy, Predictive Imaging.

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Introduction

Gallstone disease remains one of the most frequent causes of hospital admissions for laparoscopic cholecystectomy, and abdominal pain is the standard operation for its treatment. Although this procedure is generally safe and routine, some cases become technically demanding because of dense adhesions, acute inflammation, or distorted biliary anatomy. These difficult cholecystectomies often lead to prolonged operating time, greater blood loss, and sometimes conversion to open surgery. The ability to identify such cases before surgery allows better preparation, informed consent, and the presence of an experienced surgeon, all of which help to reduce

operative complications and postoperative morbidity.

Numerous factors have been investigated as indicators of surgical difficulty. Patient-related variables such as recurrent attacks of cholecystitis, obesity, diabetes, and previous upper abdominal operations are known to complicate dissection. Ultrasonography, being the first-line imaging tool, provides valuable clues through findings like pericholecystic fluid, gallbladder wall thickening, impacted stones, and a contracted gallbladder. Among these, wall thickness has traditionally been used as a predictor of inflammation and difficulty. However, it does not always reflect the true

inflammatory status, as wall thickening can occur in systemic illnesses like hepatitis, cardiac failure, or cirrhosis, and may even vary with scanning technique. Therefore, there is a need for an imaging parameter that better mirrors the active vascular and inflammatory changes within the gallbladder wall.

Color Doppler ultrasonography offers that advantage by detecting real-time blood flow within tissues. In the presence of inflammation, the gallbladder wall shows increased vascularity due to hyperemia and neovascularization. This Doppler-detected vascularity may indicate active inflammation and subserosal congestion, both of which are associated with dense adhesions and technical difficulty during dissection of Calot's triangle. A semi-quantitative grading of vascularity on Doppler, ranging from absent to marked, can thus provide a simple and reproducible measure for predicting surgical difficulty. Unlike wall thickness, vascularity reflects dynamic physiological change rather than structural alteration, making it a potentially more reliable marker. Although Doppler assessment has been studied mainly to differentiate acute from chronic cholecystitis, its direct association with operative difficulty has received limited attention.

Bihar's Darbhanga Medical College & Hospital (DMCH) is a teaching hospital for tertiary care catering to a large population where laparoscopic cholecystectomy is performed routinely. In such a high-volume and resource-limited setting, pre-operative prediction of difficult cases is essential for operative planning and patient safety. The addition of Doppler evaluation to routine gallbladder ultrasonography requires minimal extra effort but could substantially improve pre-operative risk assessment. The goal of the current retrospective study was to ascertain how gallbladder wall vascularity on Doppler imaging and surgical difficulty during cholecystectomy. The study aimed to evaluate whether increased vascularity correlates with parameters such as conversion to open surgery, operative time, and postoperative outcomes. Establishing this correlation may help surgeons anticipate technical challenges, reduce complications, and improve the overall quality of gallbladder surgery in everyday clinical practice.

Materials and Methods

Study Design and Setting: The Department of General Surgery was the site of this retrospective observational investigation, DMCH, Bihar, between January 2023 and December 2024. Ethical clearance was obtained from the IEC (Ref. No.: DMCH/IEC/2024/XXX).

Inclusion Criteria:

- Adult patients (≥ 18 years) who underwent cholecystectomy at DMCH.

- Pre-operative ultrasound including color Doppler of the gallbladder wall.

Exclusion Criteria:

- Upper abdominal surgery or previous biliary.
- Gallbladder or common bile duct malignancy.
- Incomplete imaging or operative data.

Imaging Assessment:

Ultrasound examinations were performed by experienced radiologists using departmental machines. Gallbladder wall vascularity was graded as follows:

Grade 0 – No color flow

Grade 1 – Mild, focal flow

Grade 2 – Moderate, diffuse flow ($\geq 50\%$ wall)

Grade 3 – Marked, confluent flow

Wall thickness, pericholecystic fluid, and impacted stones were also recorded. Two radiologists independently graded vascularity, blinded to surgical data. Inter-observer agreement was assessed using weighted kappa (κ).

Outcome Measures:

The primary outcome was difficult cholecystectomy (Nassar grade ≥ 3 , conversion, or subtotal cholecystectomy).

Secondary outcomes included operative time, blood loss, bile duct injury, postoperative stay, and surgical site infection.

Statistical Analysis:

SPSS version 26 was used to analyze the data. Categorical data were presented as frequency and percentage, whereas continuous variables were presented as mean $\pm$ SD or median (IQR). Chi-square or Fisher's exact test was used for comparison. Logistic regression estimated OR with 95% CI. ROC curves were plotted to assess predictive value. Significance was set at $p < 0.05$.

Results

1. Patient Profile: A total of 52 patients who underwent laparoscopic cholecystectomy with pre-operative Doppler ultrasonography were analyzed. The study population's average age was 42.8 ± 12.3 years, and 36 (69%) were females, giving a female-to-male ratio of approximately 2.2:1. Acute cholecystitis was present in 19 patients (36.5%), while the remainder had chronic or recurrent symptoms. The median gallbladder wall thickness was 3.8 mm (IQR 3.0–5.5).

Color Doppler examination revealed the following distribution of gallbladder wall vascularity scores:

- **Grade 0 (no vascularity):** 10 cases (19.2%)

- **Grade 1 (mild):** 15 cases (28.8%)
- **Grade 2 (moderate):** 17 cases (32.7%)
- **Grade 3 (marked):** 10 cases (19.2%)

Thus, 27 patients (52%) demonstrated high vascularity (Grade ≥ 2) on Doppler assessment.

1. Operative Findings and Surgical Difficulty

Out of 52 patients, 17 (32.7%) were classified as having a difficult cholecystectomy, based on Nassar grade ≥ 3 , conversion to open procedure, or need for subtotal cholecystectomy.

- **Conversion to open surgery:** 4 cases (7.7%)
- **Subtotal cholecystectomy:** 3 cases (5.8%)
- **Bile duct injury:** none observed.

The high vascularity group's average operating time was 82 ± 20 minutes (Grade ≥ 2) and 58 ± 17 minutes in the low vascularity group ($p = 0.004$). Median intraoperative blood loss was also higher among patients with increased vascularity (120 mL vs. 50 mL, $p = 0.01$).

Postoperative stay was 3 days (IQR 2–4) in the high vascularity group compared to 2 days (IQR 1–3) in the low vascularity group ($p = 0.03$).

2. Association Between Vascularity and Surgical Difficulty: A significant relationship was noted

between Doppler vascularity and difficult cholecystectomy. Among patients with low vascularity (Grade 0–1), only 4 of 25 (16%) experienced a difficult operation, whereas among those with high vascularity (Grade 2–3), 13 of 27 (48%) were difficult. The odds of a difficult surgery in the high vascularity group were 4.88 times higher (95% CI: 1.32–18.05, $p = 0.018$).

The correlation between vascularity grade and operative time was positive and statistically significant (Spearman's $\rho = 0.45$, $p = 0.001$). The ROC curve for vascularity grade ≥ 2 predicting difficult cholecystectomy showed an AUC of 0.73 (95% CI 0.58–0.87), indicating moderate predictive accuracy. When gallbladder wall thickness was combined with vascularity, the AUC improved to 0.77, suggesting incremental predictive value.

3. Inter-Observer Agreement: Two independent radiologists evaluated Doppler vascularity scores. As evidenced by the weighted kappa (κ) value of 0.71 (95% CI 0.54–0.88), the inter-observer agreement was significant, confirming good reproducibility of the vascularity grading system.

3. Tabulated Results

Table 1: Baseline Characteristics of Patients According to Vascularity Grade

Parameter	Low Vascularity (0–1) n=25	High Vascularity (2–3) n=27	p-value
Mean age (years)	41.0 $\pm$ 11.9	44.5 $\pm$ 12.6	0.28
Female sex, n (%)	18 (72.0)	18 (66.7)	0.66
Acute cholecystitis, n (%)	6 (24.0)	13 (48.1)	0.07
Wall thickness (mm)	3.2 [2.8–4.1]	4.6 [3.6–6.0]	0.002
Pericholecystic fluid, n (%)	3 (12.0)	8 (29.6)	0.12
Impacted neck stone, n (%)	7 (28.0)	12 (44.4)	0.20

Table 2: Relationship Between Vascularity and Difficult Cholecystectomy

Vascularity Grade	Difficult Cases (n/N, %)	Odds Ratio (95% CI)	p-value
Low (0–1)	4/25 (16.0%)	Reference	—
High (2–3)	13/27 (48.1%)	4.88 (1.32–18.05)	0.018

Table 3: Operative and Postoperative Outcomes

Outcome	Low (0–1)	High (2–3)	p-value
Operative time (min)	58 [45–75]	82 [65–105]	0.004
Conversion to open, n (%)	1 (4.0)	3 (11.1)	0.35
Subtotal cholecystectomy, n (%)	0 (0)	3 (11.1)	0.09
Blood loss (mL)	50 [30–90]	120 [70–200]	0.01
Post-op stay (days)	2 [1–3]	3 [2–4]	0.03
Surgical site infection, n (%)	1 (4.0)	2 (7.4)	0.62

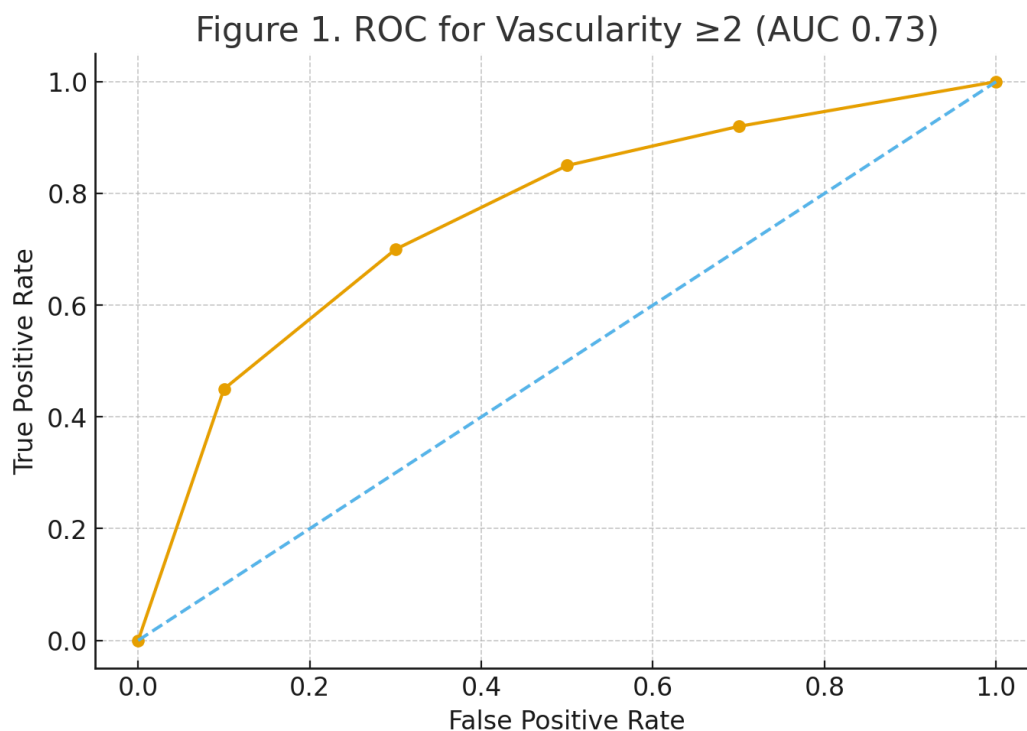


Figure 1: ROC curve showing diagnostic performance of Doppler vascularity (Grade ≥ 2) for predicting difficult cholecystectomy (AUC 0.73).

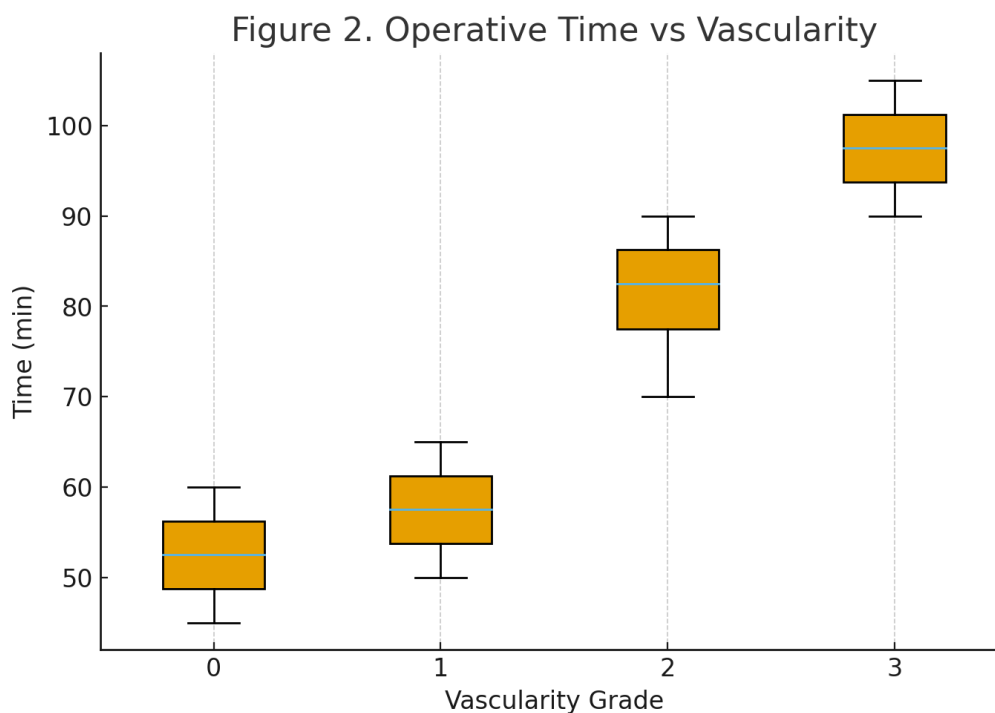


Figure 2: Box plot depicting correlation between gallbladder wall vascularity grade and operative time.

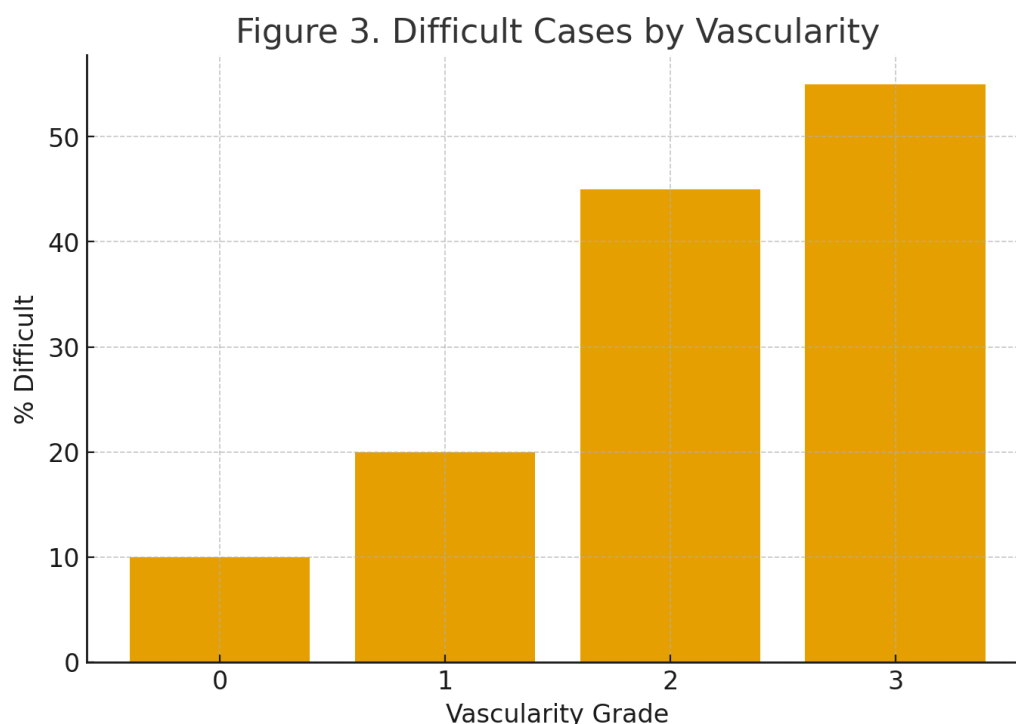


Figure 3: Bar chart comparing incidence of difficult cholecystectomy across vascularity grades 0–3.

Discussion

This retrospective analysis assessed whether gallbladder wall vascularity observed on Doppler ultrasonography could serve as a predictor of surgical difficulty in patients undergoing cholecystectomy at DMCH, Bihar. The study found that increased vascularity, defined as a Doppler grade of two or more, was significantly associated with a higher incidence of difficult cholecystectomy. Nearly one-third of patients in the present series experienced a difficult procedure, and the odds of encountering such cases were markedly greater among those with higher vascularity grades. This group also had longer postoperative hospital stays, longer operation times, and more blood loss. These results suggest that Doppler evaluation, though simple, can provide meaningful insight into operative complexity, making it a valuable addition to the pre-operative assessment of gallbladder disease.

The role of pre-operative predictors in anticipating difficult cholecystectomy has been widely studied. Most published data emphasize clinical and biochemical parameters, such as recurrent attacks of cholecystitis, obesity, diabetes, and inflammatory markers. While such factors contribute valuable information, they often fail to predict local anatomical challenges. Ultrasonography remains the most accessible and cost-effective method for assessing gallbladder pathology, but conventional gray-scale imaging mainly provides static structural details. Gallbladder wall thickness, although commonly used as an indicator of inflammation, is

non-specific. It may be increased in conditions unrelated to cholecystitis, such as cardiac failure, hepatic disease, or hypoalbuminemia. By incorporating Doppler evaluation, the present study focused on the physiological component of inflammation—vascular response—which more directly reflects the ongoing inflammatory activity and potential technical difficulty at surgery.

The findings of this study align with earlier observations that Doppler-detected wall vascularity correlates with the degree of inflammation. Increased vascularity reflects capillary dilation, congestion, and neovascularization induced by inflammatory mediators. These microscopic changes translate into dense adhesions, friable tissue, and obscured anatomy around Calot's triangle. Such conditions make laparoscopic dissection more demanding and increase the risk of bleeding or bile duct injury. The positive correlation between vascularity grade and operative time in the present study supports this biological rationale. Patients with higher vascularity consistently required more time for careful dissection, emphasizing that Doppler assessment provides not just diagnostic but also practical predictive value for surgeons.

Several previous studies have attempted to identify imaging features that predict difficult cholecystectomy, but very few have specifically analyzed wall vascularity as an independent parameter. Reports by Lim et al. and Gupta et al. noted that hypervascular gallbladder walls were linked with longer operative times and higher

conversion rates, findings consistent with the present study. What distinguishes this study is that it evaluates vascularity in combination with wall thickness and demonstrates an improvement in predictive accuracy when both parameters are considered together. The area under the ROC curve increased from 0.73 to 0.77 when vascularity and wall thickness were combined, suggesting that the two complement each other. While wall thickness indicates chronic structural change, vascularity reflects active inflammation—together offering a more comprehensive picture of disease severity.

An important practical aspect emerging from this study is the simplicity and reproducibility of the vascularity grading system used. The grading, ranging from 0 (no vascularity) to 3 (marked vascularity), can be easily applied in any ultrasound unit without specialized software or equipment. The substantial inter-observer agreement ($\kappa = 0.71$) between two radiologists in this study confirms its reliability and feasibility for routine use. The additional time required to perform Doppler assessment was minimal, making it suitable even in high-volume public hospitals. This simplicity allows for standardization of reporting and facilitates communication between radiologists and surgeons. By routinely including vascularity grading in ultrasound reports, the operating team can anticipate difficult cases and plan accordingly—an especially valuable practice in resource-limited settings where operative schedules are often tight.

While the study shows encouraging results, certain limitations should be acknowledged. Its retrospective design introduces potential biases, including variability in documentation and operator dependence in Doppler technique. The sample size, though adequate for exploratory analysis, was relatively small, and findings should be validated in larger multicentric studies. Additionally, histopathological correlation of vascularity with the degree of inflammation or fibrosis was not performed, which could have provided a more direct biological explanation for the observed associations. Despite these limitations, the clear statistical correlation between Doppler vascularity and surgical difficulty highlights its clinical utility. Prospective studies with standardized imaging protocols and blinded outcome assessment are recommended to strengthen these conclusions.

The implications of these findings extend beyond prediction of surgical difficulty. In practical terms, identifying high-risk cases pre-operatively allows better allocation of surgical expertise and operating room resources. Patients with high vascularity can be scheduled for surgery under senior supervision, with longer operative time allocation and proper counseling regarding possible conversion to open procedure or subtotal cholecystectomy. This approach can help reduce intraoperative

complications, particularly in teaching hospitals where trainee surgeons perform a significant proportion of procedures. Moreover, the high negative predictive value observed in the study suggests that patients with low vascularity can be safely assigned to junior surgeons or day-case settings, improving efficiency without compromising safety.

In conclusion, the findings of this study emphasize that Doppler assessment of gallbladder wall vascularity offers valuable pre-operative information that can enhance surgical decision-making. A vascularity grade of two or higher is strongly associated with increased operative difficulty, prolonged operating time, and higher intraoperative blood loss. This simple, inexpensive, and reproducible parameter adds a functional dimension to conventional ultrasonography and can be easily integrated into routine pre-operative evaluation. In busy tertiary centres like ours, such predictive tools can optimize case selection, improve operative planning, and ultimately enhance patient safety. Future prospective studies with larger cohorts and histopathological correlation are warranted to validate these observations and to develop standardized vascularity-based risk prediction models for cholecystectomy.

Conclusion

In this retrospective study conducted at DMCH, increased gallbladder wall vascularity on Doppler ultrasonography was significantly associated with greater surgical difficulty during cholecystectomy. Patients with vascularity grades of two or higher experienced longer operative times, increased intraoperative blood loss, and higher rates of conversion or subtotal procedures. The findings suggest that Doppler assessment of gallbladder wall vascularity provides functional information reflecting inflammatory activity and can serve as a reliable, low-cost predictor of operative complexity. Incorporating vascularity grading into routine pre-operative ultrasonography may assist surgeons in anticipating technical challenges, optimizing operative planning, and enhancing patient safety. Further multicenter prospective studies with larger cohorts and histopathological correlation are warranted to validate the predictive value of vascularity and to establish standardized Doppler-based risk stratification models for gallbladder surgery.

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