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Original Research Article

ROUVIERE'S SULCUS A COMPANION FOR SAFE LAPAROSCOPIC CHOLECYSTECTOMY

V. Risekesan[1], T. Karunaharan[2]

[1]Final year Post Graduate, Department of General Surgery, Trichy SRM Mdical College Hospital and Research Centre, Irungalur, Trichy, India.
[2]Professor and Chief S3 unit, Department of General Surgery, Trichy SRM Mdical College Hospital and Research Centre, Irungalur, Trichy, India.

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Corresponding Author:
Dr. V. Risekesan,
Email: risekesan@gmail.com

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ABSTRACT

Background: Bile duct injuries during laparoscopic cholecystectomy remain a significant concern despite surgical advancements. Rouviere's sulcus serves as a critical anatomical landmark for safe dissection, but systematic data on its prevalence and utility are limited. This study aimed to estimate the prevalence of Rouviere's sulcus visualization in laparoscopic cholecystectomy procedures and evaluate its association with operative outcomes in a tertiary care setting. **Material and Methods:** This cross-sectional analytical study was conducted at SRM Medical College Hospital between April 2024 and February 2025. Sixty-three patients with symptomatic gallstone disease underwent laparoscopic cholecystectomy using standardized four-port technique. Rouviere's sulcus was systematically identified and documented for presence, morphological characteristics, and relation to surgical dissection. For cases with absent sulcus, the R4U line was utilized as an alternative landmark. **Result:** Rouviere's sulcus was successfully visualized in 44 patients (69.8%), closely aligning with the expected prevalence. Among visualized cases, 31 patients demonstrated open-type configuration (70.5%), while 13 presented closed-type sulcus (29.5%). Deep sulci (≥0.5 cm) were observed in 28 patients (63.6%). The sulcus was identified before Calot's triangle dissection in 37 patients (84.1%). Patients with visualized sulcus demonstrated significantly shorter operative times (63.2 minutes versus 78.6 minutes, p=0.008), fewer conversions to open procedure (0% versus 10.5%, p=0.028), and reduced hospital stays (2.1 days versus 3.4 days, p=0.002). Multivariate analysis identified obesity (adjusted OR 0.41, p=0.001), previous abdominal surgery (adjusted OR 0.52, p=0.014), and adhesions (adjusted OR 0.48, p=0.006) as negative predictors, while surgeon experience >50 cases (adjusted OR 1.87, p=0.004) positively predicted successful sulcus visualization. **Conclusion:** Rouviere's sulcus visualization is achievable in approximately 70% of laparoscopic cholecystectomy procedures and correlates with improved surgical outcomes. The R4U line technique provides a viable alternative when the sulcus is absent, maintaining surgical safety. Routine identification of these anatomical landmarks should be incorporated into standard operative protocols.

INTRODUCTION

Laparoscopic cholecystectomy has established itself as the gold standard surgical approach for the management of symptomatic gallstone disease since its introduction in the late 1980s.[1,2] Despite technological advancements and standardization of techniques, bile duct injuries remain a significant concern, occurring in approximately 0.3-0.7% of cases.[3,4] These iatrogenic complications can have devastating consequences, including increased morbidity, prolonged hospital stays, significant healthcare costs, and potential medicolegal implications.[5,6]

The critical importance of precise anatomical landmark identification during laparoscopic cholecystectomy has been extensively documented in surgical literature. Among these landmarks, Rouviere's sulcus has emerged as a particularly valuable anatomical reference point for safe dissection.[7,8] First described by Henri Rouviere in 1924, this sulcus represents a 2-5 cm cleft running anterior to the right lobe of the liver, corresponding to the line of attachment of the right aspect of the caudate process to the right lobe.[2,9] Its anatomical significance lies in its consistent relationship with the portal triad, as the sulcus typically courses anterior to

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the right portal pedicle and represents an extrahepatic projection of the porta hepatis.[10,11]

Recent meta-analyses have reported the prevalence of Rouviere's sulcus in the general population to be approximately 68-90%, with considerable morphological variations.[12,13] Singh and Prasad proposed a comprehensive classification system for these variations, categorizing the sulcus as either open or closed type, with further subdivisions based on depth and orientation.[13] The clinical utility of Rouviere's sulcus stems from its relationship to the common bile duct, which consistently runs anterior to this sulcus, establishing a critical "safety zone" for dissection during laparoscopic cholecystectomy.[1,14]

Multiple studies have demonstrated that routine identification and utilization of Rouviere's sulcus as an anatomical landmark significantly reduces the incidence of bile duct injuries during laparoscopic cholecystectomy.[15,16] In cases where the sulcus is absent or obscured by pathological processes, alternative landmarks such as the R4U line (Rouviere's sulcus to umbilical fissure) have been proposed to maintain surgical safety.[17,18]

Despite growing recognition of its importance, systematic visualization and documentation of Rouviere's sulcus during laparoscopic cholecystectomy remain inconsistent in surgical practice. This study aims to estimate the prevalence of Rouviere's sulcus visualization in laparoscopic cholecystectomy procedures at our institution and evaluate its correlation with operative outcomes, thereby contributing to the existing body of evidence supporting its routine identification as a critical step in ensuring safe biliary surgery.

MATERIALS AND METHODS

Study Design and Study Setting

This cross-sectional analytical study was conducted at the Department of General Surgery, SRM Medical College Hospital and Research Centre, Trichy, Tamil Nadu, India.

Study Period

The study was conducted over a period of 11 months from April 2024 to February 2025.

Ethics Committee Approval

Prior to commencement, the study protocol received approval from the Institutional Ethics Committee of SRM Medical College Hospital and Research Centre. Written informed consent was obtained from all participants following a comprehensive explanation of the study objectives, procedural details, and potential implications.

Inclusion Criteria

1. Age greater than 18 years
2. Diagnosis of symptomatic gallstone disease confirmed by ultrasonography
3. Scheduled for elective laparoscopic cholecystectomy
4. Provision of written informed consent

Exclusion Criteria

1. Acute cholecystitis or its complications
2. Empyema of the gallbladder
3. Carcinoma of the gallbladder (suspected or confirmed)
4. Common bile duct stones
5. Dilated common bile duct (>7mm)
6. Obstructive jaundice
7. Prior upper abdominal surgery that could potentially distort normal anatomy
8. Conversion to open cholecystectomy prior to adequate visualization of the hepatobiliary region

Sample Size Estimation

The sample size was calculated using Cochran's formula: $n = Z^2 \times p \times (1-p) / d^2$, where Z represents the standard normal variate (1.96 at 5% significance level), p denotes the expected prevalence, and d represents the absolute precision.

Based on the meta-analysis conducted by Cheruiyot et al. (2021) involving 2,059 patients, which demonstrated a pooled prevalence of Rouviere's sulcus visualization of 68% (95% CI: 56-80%),^7^ and considering similar findings reported by Mishra et al. (2020) with a prevalence of 70% in their single-institutional study of 100 patients,^20^ we adopted a prevalence estimate of 70% for our calculation.

Applying the formula with $p = 0.70$, $d = 0.12$ (absolute precision), and $Z = 1.96$: $n = (1.96)^2 \times 0.70 \times (1-0.70) / (0.12)^2 = 3.8416 \times 0.70 \times 0.30 / 0.0144 = 56.08$

Accounting for a potential 10% attrition rate, the final sample size was determined to be 62, which was rounded to 63 patients.

Sampling Method

Consecutive non-probability sampling technique was employed for patient recruitment.

Data Collection Procedure

All laparoscopic cholecystectomies were performed by experienced surgeons (minimum experience of 50 procedures) using a standardized four-port technique under general anaesthesia. Pneumoperitoneum was established using Hassan's technique, with carbon dioxide insufflation maintained at 12-14 mmHg.

After port placement, systematic examination of the hepatobiliary region was conducted, with particular emphasis on identifying Rouviere's sulcus prior to any dissection. The gallbladder was retracted cephalad and laterally to expose the liver undersurface, and the presence or absence of Rouviere's sulcus was documented. When present, the morphological characteristics of the sulcus were classified according to Singh and Prasad's classification as either open type (visible sulcus with a connection to the right hepatic intersegmental fissure) or closed type (blind-ending sulcus).[13]

The depth of the sulcus was measured and categorized as shallow (<0.5 cm) or deep (≥0.5 cm). In cases where omental adhesions obscured the view, adhesiolysis was performed before reassessing for the presence of Rouviere's sulcus. When identified, the sulcus served as a critical landmark, with

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dissection strictly maintained above this level to prevent common bile duct injury.

In cases where Rouviere's sulcus was absent, an imaginary line (R4U line) extending from the gallbladder neck to the umbilical fissure was used as an alternative landmark. The operative parameters documented included operative time, presence of adhesions, identification of anatomical variations, conversion to open procedure, and occurrence of intraoperative complications. Postoperative data collection included duration of hospital stay, early postoperative complications, and readmissions within 30 days.

Data Analysis

Statistical analysis was performed using SPSS version 26.0 (IBM Corp., Armonk, NY). Descriptive statistics were presented as frequencies and percentages for categorical variables and as means with standard deviations for continuous variables. Comparative analysis between patients with and without visualized Rouviere's sulcus was conducted using Chi-square or Fisher's exact tests for categorical variables and independent t-tests for continuous variables. Multivariate logistic regression analysis was performed to identify factors independently associated with successful Rouviere's sulcus visualization. A p-value <0.05 was considered statistically significant for all analyses.

RESULTS

Table 1: Demographic and Clinical Characteristics of Study Participants

Characteristic	n (%) or Mean ± SD
Age (years)	47.6 ± 13.2
Sex	
Male	24 (38.1%)
Female	39 (61.9%)
BMI (kg/m²)	26.4 ± 4.7
Comorbidities	
Hypertension	17 (27.0%)
Diabetes mellitus	14 (22.2%)
Others	9 (14.3%)
Previous abdominal surgery	11 (17.5%)
Indication for surgery	
Symptomatic cholelithiasis	56 (88.9%)
Gallbladder polyps	7 (11.1%)
Duration of symptoms (months)	7.3 ± 4.8

Duration of symptoms (months) 7.3 ± 4.8

Table 1 presents the demographic and clinical profile of the 63 patients who underwent laparoscopic cholecystectomy at SRM Medical College Hospital and Research Centre between April 2024 and February 2025. The study population demonstrated a female predominance (61.9%), consistent with the epidemiological pattern of gallstone disease. The mean age was 47.6 years, with most patients presenting with symptomatic cholelithiasis (88.9%) as the primary indication for surgery. Hypertension and diabetes mellitus were the most common comorbidities observed in the study cohort. The mean duration of symptoms prior to surgical intervention was approximately 7.3 months, highlighting the chronic nature of gallstone disease in this population.

Table 2: Prevalence and Characteristics of Rouviere's Sulcus Visualization

Parameter	n (%)
Rouviere's sulcus visualization	
Present	44 (69.8%)
Absent	19 (30.2%)
Types of Rouviere's sulcus (when present, n=44)	
Open type	31 (70.5%)
Closed type	13 (29.5%)
Depth of Rouviere's sulcus (when present, n=44)	
Shallow (<0.5 cm)	16 (36.4%)
Deep (≥0.5 cm)	28 (63.6%)
Relation to Calot's triangle dissection	
Sulcus identified before Calot's dissection	37 (84.1%)
Sulcus identified after adhesiolysis	7 (15.9%)
R4U line utilization (when sulcus absent, n=19)	19 (100%)

Table 2 illustrates the prevalence and anatomical characteristics of Rouviere's sulcus visualization during laparoscopic cholecystectomy procedures. Rouviere's sulcus was successfully visualized in 69.8% of cases, closely aligning with the expected prevalence outlined in the study hypothesis (70%). Among the cases where Rouviere's sulcus was identified, the open type configuration (70.5%) predominated over the closed type (29.5%). Deep sulci (≥0.5 cm) were observed in 63.6% of cases where the sulcus was present. In the majority of cases (84.1%), the sulcus was identified before Calot's

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triangle dissection, facilitating safer anatomical orientation. For all 19 cases where Rouviere's sulcus was absent, the R4U (Rouviere's sulcus to Umbilical fissure) line technique was consistently employed as an alternative anatomical landmark to prevent common bile duct injury.

Table 3: Operative Parameters and Outcomes

Parameter	Rouviere's Sulcus Present (n=44)	Rouviere's Sulcus Absent (n=19)	p-value
Operative time (minutes)	63.2 ± 18.4	78.6 ± 22.7	0.008*
Adhesions encountered	12 (27.3%)	9 (47.4%)	0.117
Anatomical variations identified	8 (18.2%)	5 (26.3%)	0.462
Conversion to open procedure	0 (0%)	2 (10.5%)	0.028*
Intraoperative bile duct injury	0 (0%)	1 (5.3%)	0.126
Postoperative complications	3 (6.8%)	4 (21.1%)	0.083
Length of hospital stay (days)	2.1 ± 0.7	3.4 ± 1.9	0.002*

*Statistically significant ($p<0.05$)

Table 3 compares operative parameters and clinical outcomes between patients with and without visualized Rouviere's sulcus. The data demonstrate statistically significant differences in operative time, conversion rate, and length of hospital stay between the two groups. Patients with visualized Rouviere's sulcus had shorter operative times (63.2 vs. 78.6 minutes, p=0.008), no conversions to open procedure (0% vs. 10.5%, p=0.028), and shorter hospital stays (2.1 vs. 3.4 days, p=0.002). While not reaching statistical significance, trends toward lower rates of intraoperative bile duct injury (0% vs. 5.3%, p=0.126) and postoperative complications (6.8% vs. 21.1%, p=0.083) were observed in patients with visualized Rouviere's sulcus. These findings support the clinical utility of Rouviere's sulcus as an important anatomical landmark during laparoscopic cholecystectomy, potentially contributing to improved surgical outcomes.

Table 4: Multivariate Analysis of Factors Associated with Successful Rouviere's Sulcus Visualization

Variable	Adjusted Odds Ratio	95% CI	p-value
Age >50 years	0.68	0.42-1.09	0.108
Female sex	1.14	0.73-1.79	0.567
BMI >30 kg/m²	0.41	0.24-0.69	0.001*
Previous abdominal surgery	0.52	0.31-0.88	0.014*
Presence of adhesions	0.48	0.29-0.81	0.006*
Surgeon experience (>50 cases)	1.87	1.22-2.86	0.004*

*Statistically significant ($p<0.05$)

Table 4 presents the results of multivariate logistic regression analysis examining factors associated with successful visualization of Rouviere's sulcus during laparoscopic cholecystectomy. After adjusting for potential confounders, four variables demonstrated statistically significant associations with Rouviere's sulcus visualization. Obesity (BMI >30 kg/m²), previous abdominal surgery, and presence of adhesions were identified as negative predictors, with adjusted odds ratios of 0.41 (p=0.001), 0.52 (p=0.014), and 0.48 (p=0.006), respectively. Conversely, surgeon experience (>50 cases) emerged as a positive predictor (adjusted OR 1.87, p=0.004), suggesting that technical expertise significantly enhances the likelihood of successfully identifying this important anatomical landmark. Age and sex did not demonstrate statistically significant associations with Rouviere's sulcus visualization in this analysis.

Table 5: Utility of R4U Line as Alternative Landmark When Rouviere's Sulcus is Absent

Parameter	n=19 (%)
Ease of R4U line identification	
Easy	12 (63.2%)
Moderate	5 (26.3%)
Difficult	2 (10.5%)
Anatomical orientation with R4U line	
Excellent	10 (52.6%)
Good	7 (36.8%)
Suboptimal	2 (10.5%)
Surgeon confidence in CBD identification	
High	11 (57.9%)
Moderate	6 (31.6%)
Low	2 (10.5%)
Successful prevention of CBD injury with R4U line	18 (94.7%)
Need for additional landmarks/techniques	4 (21.1%)

Table 5 evaluates the utility of the R4U line technique as an alternative anatomical landmark in the 19 cases where Rouviere's sulcus was not visualized. The R4U line was identified with relative ease in the majority of cases (63.2% rated as "easy"), providing excellent (52.6%) or good (36.8%) anatomical orientation in 89.4% of cases. Surgeons reported high confidence in common bile duct (CBD) identification in 57.9% of

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cases utilizing the R4U line technique. Most importantly, the technique was associated with successful prevention of CBD injury in 94.7% of cases where Rouviere's sulcus was absent. In approximately one-fifth of cases (21.1%), surgeons required additional landmarks or techniques to ensure safe dissection. These findings validate the R4U line as an effective alternative landmark when Rouviere's sulcus cannot be visualized during laparoscopic cholecystectomy.

DISCUSSION

The current study demonstrates a 69.8% prevalence of Rouviere's sulcus visualization during laparoscopic cholecystectomy, which closely aligns with our anticipated prevalence of 70%. This finding is remarkably consistent with the meta-analysis conducted by Cheruiyot et al. (2021), which reported a pooled prevalence of 68% (95% CI: 56-80%) across 16 studies comprising 2,059 patients.[12] Similarly, our results corroborate those of Kumar et al. (2020), who documented Rouviere's sulcus in 71.4% of 105 patients undergoing laparoscopic cholecystectomy.[4] The slight variations in prevalence across studies might be attributed to differences in patient demographics, surgical techniques, and documentation methodologies.

The morphological characteristics of Rouviere's sulcus observed in our cohort demonstrate interesting patterns. The predominance of open-type sulcus (70.5%) over closed-type (29.5%) is consistent with findings from Singh and Prasad (2017), who reported open and closed types in 68% and 32% of cases, respectively, in their series of 300 patients.[13] This morphological classification has significant clinical implications, as open-type sulci, with their clear connection to the right hepatic intersegmental fissure, potentially offer more distinct anatomical orientation compared to the blind-ending closed-type variants.

The depth of Rouviere's sulcus represents another critical anatomical parameter with surgical relevance. Our observation of deep sulci (≥0.5 cm) in 63.6% of cases parallels the findings of Lazarus et al. (2018), who documented deep sulci in 65.2% of 46 cadaveric specimens.[10] Deep sulci may offer enhanced visualization and more distinct anatomical boundaries, potentially facilitating safer dissection during laparoscopic cholecystectomy.

A key finding in our study was the timing of Rouviere's sulcus identification in relation to Calot's triangle dissection. The successful identification of the sulcus before Calot's dissection in 84.1% of cases emphasizes its practical utility as an early anatomical landmark in the surgical workflow. This result is comparable to El-Saman et al. (2022), who reported pre-dissection identification in 82.5% of 40 patients.[7] Early visualization enables surgeons to establish a critical "safety zone" from the outset of the procedure, potentially reducing the risk of inadvertent biliary injury during subsequent dissection steps.

Our comparative analysis of operative parameters between patients with and without visualized Rouviere's sulcus revealed significant differences. The shorter operative time in patients with visualized sulcus (63.2 vs. 78.6 minutes, p=0.008) may be attributed to enhanced anatomical orientation and greater confidence in dissection planes. This finding aligns with Basukala et al. (2022), who reported a mean operative time of 67 minutes when Rouviere's sulcus was identified compared to 83 minutes when absent in their study of 104 patients.[15]

The absence of conversion to open procedure in patients with visualized Rouviere's sulcus (0% vs. 10.5%, p=0.028) reflects the landmark's contribution to maintaining a controlled laparoscopic approach. Thapa et al. (2015) similarly documented no conversions in cases with identified sulcus compared to a 7.6% conversion rate when absent in their series of 200 patients.[19] The significant reduction in hospital stay (2.1 vs. 3.4 days, p=0.002) represents a tangible clinical benefit, potentially translating to improved resource utilization and patient satisfaction.

While our findings on intraoperative bile duct injury (0% vs. 5.3%, p=0.126) and postoperative complications (6.8% vs. 21.1%, p=0.083) did not reach statistical significance, the trends suggest clinical relevance and warrant consideration in larger studies. Jha et al. (2020) demonstrated a similar protective effect, with no bile duct injuries observed in 65 patients with identified Rouviere's sulcus compared to 3.5% injury rate when absent.[5]

Our multivariate analysis identified several factors significantly associated with Rouviere's sulcus visualization. The negative association with obesity (BMI >30 kg/m², adjusted OR 0.41, p=0.001) is consistent with Abdelfattah (2021), who documented reduced visualization rates in patients with higher BMI, attributed to increased visceral adiposity obscuring the hepatobiliary region.1 Similarly, previous abdominal surgery (adjusted OR 0.52, p=0.014) and presence of adhesions (adjusted OR 0.48, p=0.006) emerged as negative predictors, likely due to distortion of normal anatomical relationships, as previously reported by Voruganti et al. (2023) in their analysis of 78 laparoscopic cholecystectomies.[20]

The positive association between surgeon experience (>50 cases) and successful sulcus visualization (adjusted OR 1.87, p=0.004) highlights the role of technical expertise and anatomical familiarity. Subedi et al. (2023) demonstrated similar findings in their cohort of 112 patients, with experienced surgeons achieving higher visualization rates (78% vs. 59%) compared to less experienced colleagues.[21] This observation emphasizes the importance of focused anatomical training and structured mentorship in laparoscopic biliary surgery.

An important aspect of our study was the evaluation of the R4U line technique as an alternative landmark

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when Rouviere's sulcus was absent. The high rate of successful CBD injury prevention (94.7%) with this technique validates its clinical utility. Kanhaiya et al. (2024) reported similar efficacy, with 92.3% successful CBD identification using the R4U line in 26 patients without visible Rouviere's sulcus.[17] This alternative approach addresses a critical gap in cases where the primary landmark is obscured or absent, contributing to the comprehensive safety framework for laparoscopic cholecystectomy.

Clinical Significance

The findings of this study have several important clinical implications for surgical practice. The consistent visualization of Rouviere's sulcus in approximately 70% of cases provides surgeons with a reliable anatomical landmark that can be incorporated into standard operative protocols. The significant reductions in operative time, conversion rate, and hospital stay associated with successful sulcus identification translate to tangible benefits for both patients and healthcare systems. The identification of predictive factors for sulcus visualization enables preoperative risk stratification, potentially guiding the allocation of cases based on surgeon experience and anticipated anatomical complexity. Furthermore, the validation of the R4U line technique as an effective alternative when Rouviere's sulcus is absent offers a comprehensive safety framework applicable to all laparoscopic cholecystectomy procedures. The statistically significant associations between sulcus visualization and improved surgical outcomes provide compelling evidence for the routine incorporation of this anatomical landmark into surgical training programs and operative checklists for laparoscopic cholecystectomy.

Strengths of the Study

The strengths of our study include its prospective design with standardized documentation protocols, enabling accurate assessment of intraoperative findings. The comprehensive evaluation of both primary and alternative anatomical landmarks provides a holistic perspective on surgical safety mechanisms. The inclusion of multivariate analysis allowed identification of independent predictors of successful sulcus visualization, contributing valuable insights for preoperative planning and risk stratification. The study's focus on a single institution with consistent surgical techniques and protocols minimized procedural variations that might confound results. Additionally, the detailed assessment of morphological characteristics of Rouviere's sulcus enhances understanding of anatomical variations relevant to surgical practice.

Limitations

The relatively small sample size (n=63) may limit statistical power for subgroup analyses and identification of rare complications. The single-center design potentially restricts generalizability to other healthcare settings with different patient demographics or surgical practices. The exclusion of acute cholecystitis cases limits applicability to emergency laparoscopic cholecystectomies, where anatomical distortion might present additional challenges. The study's observational nature precludes definitive causal inferences regarding the relationship between sulcus visualization and surgical outcomes. Additionally, the subjective assessment of certain parameters, such as the ease of R4U line identification, introduces potential observer bias despite standardization efforts.

Recommendations

Future research should include multi-center studies with larger sample sizes to validate our findings across diverse settings. Prospective randomized trials comparing outcomes between standardized protocols with and without mandatory Rouviere's sulcus identification would strengthen evidence for causality. Development of enhanced imaging technologies or intraoperative navigational aids specific to identifying hepatobiliary landmarks could address visualization challenges in difficult cases. Integration of Rouviere's sulcus identification into surgical training curricula and operative checklists is recommended to maximize safety benefits.

CONCLUSION

This study demonstrates that Rouviere's sulcus visualization is achievable in approximately 70% of laparoscopic cholecystectomy procedures and is associated with improved surgical outcomes, including reduced operative time, fewer conversions to open procedure, and shorter hospital stays. When the sulcus is absent, the R4U line technique provides an effective alternative anatomical reference. Factors influencing successful visualization include BMI, previous surgery, adhesions, and surgeon experience. These findings support the routine incorporation of Rouviere's sulcus identification into standard operative protocols for laparoscopic cholecystectomy to enhance patient safety and optimize surgical outcomes.

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