

Morphological Analysis of Rouviere's Sulcus in Laparoscopic Cholecystectomy: A Cross-sectional Study

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ABSTRACT

Introduction: Laparoscopic Cholecystectomy (LC) is the gold standard for the management of gallbladder disease; however, the loss of tactile feedback increases the risk of Bile Duct Injury (BDI). Rouviere's Sulcus (RS) serves as an important extrabiliary anatomical landmark that helps define a safe plane of dissection during surgery.

Aim: To determine the prevalence, morphological variants, and morphometric dimensions of RS and to evaluate its association with demographic characteristics in patients undergoing elective LC.

Materials and Methods: This hospital-based cross-sectional study was conducted from January 2024 to June 2025 in the Department of General Surgery, Sri Guru Ram Das Institute of Medical Sciences and Research, Amritsar, Punjab, India. Hundred adult patients undergoing elective LC were included. Intraoperative visualisation and morphometric assessment of RS, including its length, width, and depth, were performed using a standardised four-port laparoscopic technique. The

sulcus was classified into four morphological types (Types I-IV) based on established criteria. Due to small subgroup sizes for certain RS variants, Fisher's exact test was used instead of Pearson's Chi-square test when expected cell counts were fewer than 5. A p-value <0.05 was considered statistically significant.

Results: The study population had a mean age of 48.24±13.73 years and comprised 78 females and 22 males (female-to-male ratio: 3.5:1). RS was identified in 80% of patients (95% CI: 71.2%-86.7%). Type I (Open type) was the predominant morphological variant, observed in 91.25% of visualised sulci, followed by Type III (5.0%), Type IV (2.5%), and Type II (1.25%). The mean length, width, and depth of Type I sulci were 21.00±10.02 mm, 2.56±1.95 mm, and 2.38±1.78 mm, respectively. No significant association was observed between RS morphology and patient age (p-value=0.626) or gender (p-value=0.848).

Conclusion: The RS is a highly consistent and reliable anatomical landmark during LC, with its morphology remaining independent of demographic factors.

Keywords: Anatomical landmark, Bile duct injury, Hepatobiliary surgery, Morphometry

INTRODUCTION

Since its introduction in the early 1990s, LC has revolutionised the surgical management of gallbladder disease, becoming the gold standard for treating everything from symptomatic cholelithiasis to acute cholecystitis. While the shift from open surgery to a minimally invasive approach has delivered clear clinical advantages-such as decreased postoperative pain, shorter hospitalisations, and faster recovery-it has also introduced specific technical hurdles [1].

The most significant constraint of LC is the loss of direct tactile feedback. Surgeons must rely on two-dimensional visual cues to navigate biliary anatomy that is often complex and highly variable. This change in operative perception contributed to an initial rise in bile duct injuries, which currently occur in roughly 0.3% to 0.7% of procedures [1,2]. To address these risks, the Critical View of Safety (CVS) was developed as the intraoperative standard. However, achieving a clear CVS remains challenging in the presence of intense inflammation, chronic fibrosis, or significant anatomical anomalies.

Consequently, the identification of consistent, extra-biliary landmarks-most notably RS-has become an indispensable component of the modern surgical repertoire. By providing a fixed reference point delineating the safe plane of dissection superior to the Common Bile Duct (CBD), RS serves as a valuable anatomical guide that enhances surgical precision, lowers the threshold for conversion to open surgery, and ultimately safeguards the patient against devastating vasculobiliary complications [3].

Even when the gallbladder is distorted or shrunken by severe chronic cholecystitis, RS remains a remarkably consistent and reliable reference for intraoperative orientation. Identifying the RS is

a simple yet high-impact step that can shorten operative time and reduce complications, such as cystic artery injury or surgical site infections. Despite its proven utility, this landmark is occasionally overlooked, even by experienced clinicians [4,5].

Consequently, the present study estimated the frequency of RS in patients undergoing LC to establish baseline data regarding its various morphological types and dimensions.

MATERIALS AND METHODS

This hospital-based cross-sectional study was conducted from January 2024 to June 2025 in the Department of General Surgery, Sri Guru Ram Das Institute of Medical Sciences and Research, Amritsar, Punjab, India. The present research study received approval from the Institutional Ethics Committee (SGRD/IEC/2024-297) and the Institutional Research Committee of SGRDIMS, Amritsar, Punjab, India.

Sample size: Based on the prevalence of RS reported by Zubair M et al., (68.13%), the calculated minimum sample size was 84 patients [6]. Considering a 15% contingency for exclusions and incomplete observations, 100 patients were included.

$$n = \frac{Z^2 \times p \times (1-p)}{d^2}$$

Where: Z=1.96; p=0.6813 and d=0.10

Consecutive sampling was employed.

Inclusion criteria: All eligible patients undergoing elective LC during the study period were recruited until the desired sample size was reached.

Exclusion criteria: Exclusion criteria included previous hepatobiliary surgery, suspected gallbladder malignancy, congenital biliary anomalies, severe liver cirrhosis, conversion to open cholecystectomy, and inability to identify operative landmarks due to extensive adhesions.

Surgical protocol: A standardised four-port laparoscopic technique was utilised for all participants. Following the successful establishment of pneumoperitoneum, the gallbladder fundus was retracted medially to expose the inferior surface of the liver. RS was then identified as a primary anatomical landmark.

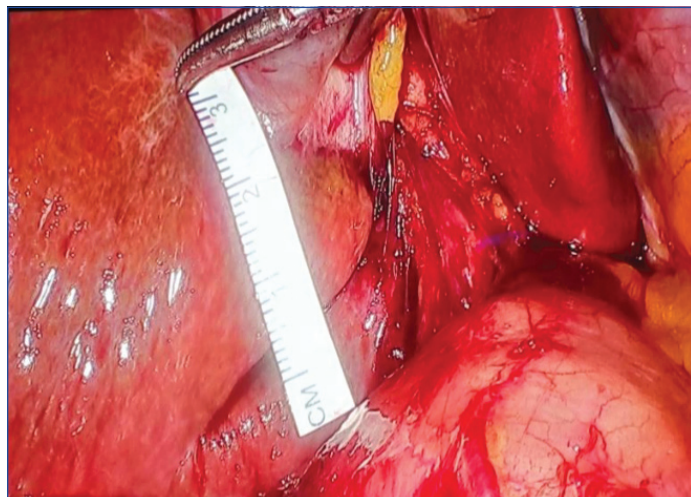
Morphometric measurement of Rouviere's Sulcus (RS): Following identification of RS, morphometric measurements were obtained intraoperatively using a sterile calibrated miniature measuring scale introduced through the 10-mm epigastric port. The length of the sulcus was measured from its medial to lateral extent, the width at its widest visible point, and the depth as the perpendicular distance from the deepest point of the sulcus to the adjacent hepatic surface. All measurements were performed under direct laparoscopic visualisation by the principal operating surgeon and independently verified by a second consultant surgeon experienced in laparoscopic hepatobiliary surgery. To minimise interobserver variability, measurements obtained by the two surgeons were compared independently. If the difference between measurements exceeded 1 mm, the measurement was repeated jointly until consensus was achieved. The consensus measurement was recorded as the final value for statistical analysis.

Methodology: The morphological characteristics of the RS in all 100 cases were categorised according to the framework established by Thapa PB et al., [7]. Each identified sulcus was assigned to one of four specific categories (Type I, II, III, or IV) based on its visual presentation and depth [Table/Fig-1].

Classification	Morphological Description
Type I:	Open type- cleft with right hepatic pedicle visualized, sulcus opened throughout its length.
Type II:	Partially fused- sulcus opened only at lateral end.
Type III:	Partially fused- sulcus opened only at medial end.
Type IV:	Fused type- pedicle not visualized or absent sulcus.

[Table/Fig-1]: Classification of Rouviere's Sulcus.

Intraoperative identification technique: The visualisation of RS was achieved by applying cephalad and leftward traction to the gallbladder neck. This maneuver effectively opens the space on the right-side of the hepatic hilum, exposing the sulcus. Anatomically, the landmark was consistently localised on the posterior aspect of the hepatobiliary triangle, typically oriented obliquely relative to the anterior-external margin of the liver [Table/Fig-2].



[Table/Fig-2]: Intraoperative laparoscopic view demonstrating morphometric measurement of Rouviere's Sulcus (RS). A sterile calibrated miniature measuring scale introduced through the 10-mm epigastric port is used to measure the dimensions of RS under direct laparoscopic visualisation.

Measurement of gallbladder and biliary parameters: Gallstone size was determined intraoperatively by measuring the largest diameter of the extracted gallstone using a sterile graduated measuring scale and was recorded in millimeters (mm). Gallbladder (GB) wall thickness was assessed intraoperatively at the thickest visible portion of the gallbladder wall using the calibrated miniature measuring scale introduced through the 10-mm epigastric port. CBD diameter was measured intraoperatively at its widest visible segment after adequate exposure of the hepatobiliary anatomy. Gallbladder distension status was assessed visually during laparoscopy and categorised as normally distended, partially distended, or contracted based on the degree of gallbladder expansion and wall collapse. All measurements were performed by the principal surgeon and independently verified by a second consultant surgeon.

STATISTICAL ANALYSIS

Statistical analysis was performed using IBM Statistical Package for the Social Sciences (SPSS) Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean±standard deviation, whereas categorical variables were expressed as frequency and percentage. Due to small subgroup sizes for certain RS variants, Fisher's exact test was used instead of Pearson's Chi-square test when expected cell counts were fewer than 5. A p-value <0.05 was considered statistically significant.

RESULTS

The study cohort consisted of 100 patients with a mean age of 48.24±13.73 years, with the highest concentration of participants falling within the 41-50 year age (26%) [Table/Fig-3].

Category	Variables	n (%) / Mean±SD
Age (years)	≤30	8 (8.0)
	31-40	25 (25.0)
	41-50	26 (26.0)
	51-60	22 (22.0)
	61-70	11 (11.0)
	>70	8 (8.0)
	Mean age	48.24±13.73
Gender	Female	78 (78.0)
	Male	22 (22.0)
	Female: Male Ratio	3.5:1
Laboratory	Haemoglobin (g/dL)	11.14±1.86
	TLC (/mm ³)	7468.90±1991.98
	Total Bilirubin (mg/dL)	0.64±0.40
	SGOT / SGPT (IU/L)	48.42±47.56/54.14±76.31

[Table/Fig-3]: Baseline demographic and clinical characteristics of the study population (n=100).

Values are expressed as mean ± standard deviation (SD) or frequency (%). SGOT: Serum glutamic oxaloacetic transaminase; SGPT: Serum glutamic pyruvic transaminase; TLC: Total leucocyte count

Gallstone size varied significantly, with a mean diameter of 9.22±5.61 mm, ranging from small 1.50 mm calculi to larger 27.00 mm stones [Table/Fig-4].

Parameters	Minimum (mm)	Maximum (mm)	Mean±SD (mm)
GB stone size	1.50	27.00	9.22±5.61
GB wall thickness	1.50	6.00	3.38±1.03
CBD diameter	4.50	10.00	6.33±2.34
Distension status	Normally distended	Partially distended	Contracted
Frequency (n=100)	86 (86%)	12 (12%)	2 (2%)

[Table/Fig-4]: Intraoperative morphometry of the gallbladder and biliary structures (n=100).

GB: Gallbladder; CBD: Common bile duct; SD: Standard deviation. Values are presented as mean±SD or n (%). Measurements were obtained intraoperatively under direct laparoscopic visualisation

The RS was identified in 80 of 100 patients, yielding a prevalence of 80.0% (95% CI: 71.2%-86.7%), with the Type I (Open) morphology being overwhelmingly predominant at 91.25% (n=73). This most common variant exhibited mean dimensions of 21.00±10.02 mm in length and 2.38±1.78 mm in depth [Table/Fig-5].

RS type	n (%)	Length (mm)	Width (mm)	Depth (mm)
Type I (Open)	73 (91.25)	21.00±10.02	2.56±1.95	2.38±1.78
Type II	1 (1.25)	40.00*	0.50	0.50
Type III	4 (5.00)	27.50±17.08	2.33±0.58	3.00±2.31
Type IV (Fused)	2 (2.50)	50.00*	2.00±1.41	-
Total Visualised	80 (80.0)	-	-	-

[Table/Fig-5]: Morphological classification and morphometric dimensions of Rouviere's Sulcus (RS) (n=80).

*Single observation; SD not applicable; ** Depth was not measurable in Type IV (Fused) RS because the sulcus was anatomically fused/obliterated, resulting in the absence of a distinct groove or cavity from which depth could be measured. Width could be measured externally; Depth was not measurable because the fused sulcus lacked a distinct cavity

Among the 80 visualised cases, the distribution of RS types across different age brackets showed no significant variation (p-value=0.626). Similarly, gender did not act as a significant predictor of sulcus type (p-value=0.848) [Table/Fig-6].

Variables	Type I (n=73)	Type II (n=1)	Type III (n=4)	Type IV (n=2)	p-value
Age group (years)					0.626
≤40	22	1	3	0	
41-60	37	0	1	1	
>60	14	0	0	1	
Gender					0.848
Female	59 (80.8)	1	3	2	
Male	14 (19.2)	0	1	0	

[Table/Fig-6]: Association of Rouviere's Sulcus (RS) morphological variants with patient demographics (n=80).

p-values were derived using Fisher's-exact Test owing to small subgroup frequencies

DISCUSSION

The study's demographic profile closely aligns with the classic "four Fs" paradigm (fat, fertile, female, forty), showing a 3.5:1 female-to-male ratio and a peak incidence in the fifth decade. The present study's mean age mirrors data from Thapa PB et al., Arora B and Ranga HR, confirming a stable middle-age predominance regardless of minor variations in paediatric or elderly subsets reported by Jha AK et al., [7-9]. The significant female preponderance (78%) was consistent with oestrogen-mediated cholesterol supersaturation, falling between the ratios reported by Al-Naser MK (70.6%) and Parsa H et al., (5:1) [3,10].

A prospective study was conducted on 290 patients with gallbladder disease undergoing LC, including 250 non-cirrhotic patients (Group A) and 40 cirrhotic patients (Group B). In Group A, RS was identified as a deep sulcus in 190 patients (76%), as a scar in 40 patients (16%), and was absent in 20 patients (8%). In Group B, RS was observed as a deep sulcus in nine patients (22.5%) and as a scar in 11 patients (27.5%), whereas it was absent in 20 patients (50%) [11].

The 80% visualisation frequency of RS in this cohort aligns closely with the meta-analytic pooled prevalence of 83% reported by Cheruiyot I et al., and the 81.3% reported by Paul V et al., [12,13]. The present study findings significantly exceed the rates identified by Jha AK et al., (63.6%) [9], Rafi YA et al., (74.8%) [14], and Thapa PB et al., (75%) [7].

Conversely, the 20% absence rate in the present study parallels the findings of Al-Naser MK 10 (20.7%) and Lazarus et al., 15 (17.3%), though it remains notably lower than the 92% frequency observed by Mishra BB et al., [10,15,16]. This difference may be attributed to variation in patient characteristics, degree of gallbladder

inflammation, contracted gallbladders, fatty liver changes, surgeon-dependent recognition, and differences in classification criteria across studies.

The overwhelming predominance of Type I (open type) at 91.25% in the current study considerably exceeds the 66% prevalence reported in the meta-analysis by Cheruiyot I et al., and the frequencies reported by Thapa PB et al., (54%) and Paul V et al., (61.5%) [7,12,13]. While the present findings also exceed the 61.9% observed by Mishra BB et al., they stand in marked contrast to the lower rates reported in cadaveric studies by Hameed O et al., (48%) and Renil A et al., (46.9%) [17,18].

The low frequency of non-open variants (Types II-IV, 8.75% total) falls below the 32.5% reported by Basukala S et al., likely reflecting a more stringent classification where subtle slits are categorised as Type I [19].

The statistical analysis confirms that the RS is a stable and consistent anatomical landmark, independent of patient demographics. The high visualisation rate across all age groups (p-value = 0.626) does not support the hypothesis that physiological extremes may obscure the sulcus, instead aligning with the non-cadaveric uniformity reported by Cheruiyot I et al., [12].

The routine identification of RS during LC has significant clinical implications. Since the sulcus consistently lies superior to the CBD, it serves as a dependable extrabiliary landmark for establishing a safe plane of dissection. Its identification complements the CVS and may reduce the risk of BDI, particularly during difficult cholecystectomies with inflammation, adhesions, or distorted anatomy. Multicentre studies involving larger patient populations are warranted to validate the prevalence and morphological spectrum of RS. Future research should investigate the relationship between RS identification and operative outcomes, including BDI, operative duration, and conversion rates.

Limitation(s)

First, it was a single-centre study with a relatively modest sample size. Second, morphometric measurements were performed intraoperatively and may be subject to minor observer-related variation despite standardised methodology. Third, the very small number of Type II, III, and IV variants limited robust comparative statistical analysis. Finally, long-term clinical outcomes such as BDI rates and operative complications were not evaluated.

CONCLUSION(S)

The RS was identified in 80% of patients undergoing elective LC, with the open type representing the predominant morphological variant. The anatomical characteristics of the sulcus demonstrated no significant association with age or gender. Given its consistent location and ease of recognition, RS serves as a valuable intraoperative landmark that can enhance surgical orientation and potentially reduce the risk of biliary injury.

Data availability statement: The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

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