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Anatomical Variations of Rouviere's Sulcus and Importance of R4U Line During Laparoscopic Cholecystectomy: A Prospective Observational Study

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ABSTRACT:

Background: Laparoscopic cholecystectomy (LC) is the gold standard for symptomatic cholelithiasis, but bile duct injuries (BDIs) remain a significant complication. Rouviere's sulcus (RS) and the R4U line are proposed anatomical landmarks to minimize BDIs. This study aims to evaluate their utility in LC.

Methods: A prospective observational study was conducted on 350 patients undergoing LC at Sharda Hospital from March 2024 to November 2025. Intraoperative findings regarding RS, the R4U line, and dissection relative to the R4U line were recorded. Postoperative BDIs were assessed.

Results: RS was present in 85.7% of patients, with the open type being most common (85.33%). The R4U line was determinable in 85.7% of patients. Dissection was above the R4U line in 93.33% of cases. Two patients experienced intraoperative BDIs. One BDI occurred in a patient with absent R4U line, and the other occurred in a patient with dissection below the R4U line. A significant association was found between dissection below the R4U line and the occurrence of BDIs (p=0.02).

Conclusion: Rouviere's sulcus is a frequently identifiable landmark during LC. Dissection below the R4U line is associated with a significantly increased risk of bile duct injuries. The R4U line is a valuable landmark for safe dissection during laparoscopic cholecystectomy.

Introduction

Laparoscopic cholecystectomy (LC) has revolutionized the surgical management of symptomatic cholelithiasis, becoming the gold standard due to its minimally invasive nature and associated benefits. However, the procedure is not without risk, with bile duct injuries (BDIs) representing a significant complication with prevalence of 0.5% to 0.8% [1]. These iatrogenic injuries, often results from misinterpretations of biliary structure and its variations leading to severe long-term morbidity. The adoption of Strasberg's Critical View of Safety (CVS) has been a cornerstone in minimizing the risk of BDIs during LC. CVS is characterized by the clear visualization of the cystic duct and artery entering the gallbladder after meticulous dissection of the hepatocystic triangle, along with exposure of lower third of cystic plate [2]. However, the variability of biliary anatomy can still pose significant challenges, even with adherence to CVS principles. Various landmarks have been identified for minimizing intra-operative complications such as BDI. Among these landmarks, Rouviere's sulcus (RS), initially described by Henrie Rouviere in 1924, present as a cleft running obliquely towards right hepatic hilum and the derived R4U line, have emerged as potentially valuable tools in guiding dissection and minimizing the risk of BDIs [3]. The R4U line, extending from the roof of the RS to the umbilical fissure across the base of segment 4, defines a safe zone for dissection, with the confluence of the common bile duct and cystic duct typically lying beneath this line [4]. Despite the potential utility of RS and the R4U line, the current literature presents a spectrum of findings regarding their reliability and clinical applicability. Studies have reported a strong correlation between these

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landmarks and the location of critical biliary structures [5]. This paper aims to synthesize current evidence on the utility of Rouviere's sulcus and the R4U line as anatomical landmarks to minimize bile duct injuries during laparoscopic cholecystectomy and discuss their clinical implications.

AIMS AND OBJECTIVES

- **Aim of the study:** To study the anatomical variation of Rouviere's sulcus and importance of R4U line in performing safe laparoscopic cholecystectomy.
- **Objective:**

  1) To study the incidence and anatomy of Rouviere's sulcus.

  2) To evaluate the dissection in relation to R4U line & analyse the CBD injury

Methods

This prospective observational study was conducted in the General Surgery Department of Sharda Hospital, Greater Noida, after ethical clearances from the Institutional Ethical Committee. The study period spanning from March 2024 to November 2025.

Patients aged 18 years and older who underwent laparoscopic cholecystectomy were included in the study.

Exclusion criteria patients:

- Patients below 18 years of age.
- With hepato-pancreato-biliary malignancy.
- Obscuration of Calot's triangle.

SAMPLE SIZE

The sample size was calculated using SLOVIN'S formula.

Since the sample size came out to be 313 so we increased the sample size to 350 to adjust for the wastage rate.

Intraoperative findings related to Rouviere's sulcus (RS) and the R4U line were meticulously documented. This included the incidence, morphology, and anatomical variations of RS. The relationship between dissection relative to the R4U line and the occurrence of bile duct injuries (BDIs) was also recorded. Post-operative complications, particularly BDIs, were assessed during the follow-up period.

Results

Demographics

Of the 350 patients, 61.7% were female (n=216) and 38.3% were male (n=134) (Table 1). The mean age was 30.94 ± 7.96 years (median: 29 years, IQR: 26-33). No significant age difference existed between genders (Table 2), though females were slightly younger (mean age: 30.29 ± 9.16 years) than males (mean age: 31.99 ± 5.39 years) (p=0.052). The most frequent age group was 26-30 years (40%) (Table 2).

Table 1: Gender wise distribution of study participants

Gender	Number	Percentage
Female	216	61.7
Male	134	38.3

Table 2: Age group wise distribution of study participants

Age group (years)	Number	Percentage
18-25	73	20.9
26-30	140	40.0
31-35	84	24.0
>35	53	15.1
	Mean ± SD	Median (IQR)
Age (years)	30.94 ± 7.96	29 (26-33)

Rouviere's Sulcus (RS) and R4U Line

RS was present in 85.7% of patients . RS types included open (85.33%, n=256), closed (9%), and slit/scar (5.66%) . The R4U line was determinable in 85.7% of patients. Dissection was above the R4U line in 93.33% and below in 6.66% .

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Table 3: Distribution of Rouviere's Sulcus among study participants

Rouviere's Sulcus present	Number	Percentage
Yes	300	85.7
No	50	14.3

Table 4: Distribution of type of Rouviere's Sulcus among study participants (N=300)

Rouviere's Sulcus Type	Number(n=300)	Percentage
Closed	27	9.00
Open	256	85.33
Scar/ Slit	17	5.66

Table 5: Distribution of study participants based on R4U line

R4U line	Number	Percentage
Present	300	85.7
Could not be determined	50	14.3

Table 6: Distribution of study participants based on Dissection Above R4U line or below in patients where R4U line was present. (n=300)

Dissection Above R4U line or Below	Number	Percentage
Above	280	93.33
Below	20	6.66

Complications and Associations

Two patients experienced intra-operative BDI. BDI occurred in one patient without RS/determinable R4U line and in one patient with dissection below the R4U line. A statistical significant association was found between the R4U plane and complications. (p=0.02).

Table 7: Association between R4U and complications among study participants

	Intra-op complications (BDI)		P value
R4U	Yes	No	
Dissection above (280)	0	280	0.02
Dissection below (20)	1	19	

The present study found no statistically significant association between sex and RS or between sex and type of Rouviere's Sulcus However, RS was found 1.16 time more in females than males as presented in following table 8 &9

Table 8: Association between Sex and RS.

	Rouviere's Sulcus presence		OR, 95% CI	P value
Sex	Yes	No		
Female	186 (84.2%)	28 (15.7%)	1.167, 0.65-2.07	0.595
Male	114 (82.08%)	22 (17.91%)		

Journal of Chemical Health Risks

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Table 9: Association between Sex and type of Rouviere's Sulcus

Sex	Number	Absent (n=50)	Closed	Scar/Slit	Open	P value
Female	N	34	14	5	146	0.081
	%	68	51.8%	29.5%	57.0%	
Male	N	16	13	12	110	
	%	32	48.1%	70.5%	42.9%	

Also no statistical significant association was found between age group and RS. However, Rouviere's Sulcus was present among 39% of the study participants in age group 26-30 years, followed by 31-35 years (24.3%), 18-25 years (21.2%) and >35 years (15.4%) as presented in table 10.

Table 10: Association between Age group and Rouviere's Sulcus presence

	Rouviere's Sulcus		P value
Age Group	Present	Absent	
18-25	62 (21.2%)	10 (19.0%)	0.878
26-30	114 (39.0%)	22 (44.8%)	
31-35	71 (24.3%)	10 (22.4%)	
>35	53 (15.4%)	8 (13.8%)	

Dilated CD was present in 1.42% & Peri-Hepatic Adhesions were present in 0.57% of the study participants. 92.8% of the study participants didn't have any other anomalies

Table 11: Distribution of study participants based on other anomalies

Other anomalies	Number	Percentage
Cystic duct was long and low insertion into CBD	1	0.28
Dilated cystic duct	5	1.42
RHD fusion with CBD	1	0.28
Moynihan's Hump	2	0.57
Over Distended GB	1	0.28
Peri-Hepatic Adhesions ? Fitz-hugh Curtis Syndrome	2	0.57
Short Cystic Duct	3	0.85

Discussion

This prospective observational study investigated the anatomical variations of Rouviere's sulcus (RS) and the significance of the R4U line in laparoscopic cholecystectomy (LC). The findings contribute to the ongoing discussion regarding strategies to minimize bile duct injuries (BDIs), a serious complication of LC.

Prevalence and Variations of Rouviere's Sulcus

The current study observed RS to be present in 85.7% of cases. This is consistent with findings from Dahmane et al[6], who reported RS presence in 82% of cases, and Singh et al [3], who reported a 90.6% visibility rate. However, other studies have reported varying rates, such as Al-Naser [7], who found RS in 79.3% of patients, and Jha et al. [8], who identified RS in 63.63% of cases. Studies by Kumar A et al [9], Basukala et al [10], Bhattarai SR et al [11], and Bajpayee SR [12] reported a 90% prevalence

The present study found that there was statistically non-significant association between age, sex and Rouviere's sulcus and type of Rouviere's sulcus. However

Journal of Chemical Health Risks

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Rouviere's sulcus was more commonly found in females. According to Kumar et al, it is believed that women's sex hormones make them more susceptible. Because oestrogen increases the formation of biliary cholesterol, bile becomes supersaturated.[9] A study by Omer OEE et alfound that that there was statistically non-significant association between sex and Rouviere's sulcus and type of Rouviere's sulcus but the frequency of Rouviere's sulcus (93.6%) and type of Rouviere's sulcus (open: 55%, closed 27.9% and scar: 10.7%) was more in females than in males.[13]

In terms of RS morphology, the open type was most common in our study (85.33%), followed by the closed type (9%). The incidence of open type RS in our study is higher as compared with other studies, as a study by Singh M et al found that among study participants 71% had deep sulcus and 23% had slit type sulcus. Singh et al divided the deep sulcus further into open (84.5%) and closed type (15.5%). Other studies have also reported similar findings of open type being most common ranging 50-70%, with variations in the proportions of each type.[3]

Importance of the R4U Line

The R4U line, a line extending from the roof of RS to the umbilical fissure across the base of segment 4, defines a safe zone for dissection during LC. In our study, the R4U line was determinable in 85.7% of patients. We observed that when dissection was performed above the R4U line, the incidence of BDI was none. Conversely, BDI occurred in patients where dissection was carried out below the R4U line. This finding highlights the crucial role of the R4U line as a reliable anatomical landmark to guide dissection and minimize the risk of BDI.

Bile Duct Injuries

Bile duct injuries (BDIs) remain a significant concern in LC. In our study, we observed two cases of BDI. One case occurred in a patient where RS was absent, and the R4U line could not be determined. The other case occurred when dissection was performed below the R4U line. This observation reinforces the importance of utilizing anatomical landmarks like RS and the R4U line.

Reviewing literature on complications, Kumar A et al observed that 4 patients developed complication namely port site hemangioma, port site hematoma, serosanguionous collection in GB fossa and BDI in patients where RS was present.[9] Basukala et al reported that one (0.15%) participant had cystic artery injury leading to uncontrolled bleeding in RS positive group while RS negative group two such cases (18.18%) and no major bile duct injuries were reported during intra operative or postoperative follow up.[10] Pathak R et al reported no injury to bile duct after the critical view of safety was achieved in patients where RS was identified.[14] Voruganti MR et al reported bleeding was seen in eight cases, bile leak was observed in five cases and wound infection was seen in 12 cases out of total 106 patients who were operated by lap cholecystectomy following Rouviere's sulcus. [15] Singh M et al reported no incidence of bile duct injury in their study.[3] Study by Ibrahim et al reported 2 cases of blood loss from GB bed (intraoperatively), biliary injury was present in 2 (1%) cases one each in Rouviere's sulcus visible and invisible group.[16]

We found that there was statistically significant association between the RS, R4U line and intra-op complications among study participants. However the complication was very less (OR: 0.0001) among those in whom the Rouviere's sulcus was present. A study by Omer et al reported high post-operative complication (10.1%) among study participants where RS was absent and low complication (4.3%) where RS was present although the association was statistically non-significant (0.470).[36] A study by Bhattarai et al found that there was statistically significant association (p=0.001) between the presence of RS and complications, the groups where RS was not found had more cystic artery injury (14.28%) than group where RS was found (1.26%).[18]

Our study emphasizes the importance of the R4U line in guiding safe dissection during LC. We found a significant association between dissection relative to the R4U line and the occurrence of BDIs, with BDIs occurring when dissection was below the R4U line. This aligns with the principles described by Gupta and Jain , who introduced the R4U planes for zonal demarcation to achieve safe LC by identifying fixed anatomical landmarks. Singh et al. combined the identification of RS with the achievement of CVS, reinforcing the significance of both landmarks in preventing bile duct injuries.

Journal of Chemical Health Risks

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JCHR (2026) 16(2), 2649-2654 | ISSN:2251-6727

Conclusion

This prospective observational study reaffirms the significance of Rouviere's sulcus (RS) as a crucial anatomical landmark in laparoscopic cholecystectomy (LC). The study provides further evidence supporting the variability in RS morphology and highlights the importance of the R4U line in guiding safe dissection during LC.

Our findings indicate that dissection below the R4U line is associated with an increased risk of bile duct injuries (BDIs), underscoring the necessity for precise anatomical identification and meticulous surgical technique.

By emphasizing the importance of utilizing these anatomical landmarks, this research contributes to the ongoing efforts to enhance surgical safety, reduce complications, and improve patient outcomes in laparoscopic cholecystectomy. This study is aligned with UN Sustainable Development Goal No.3 (Good Health and Well-being) implementation of Govt. of India.

References

1. Mischinger HJ, Wagner D, Kornprat P, Bacher H, Werkgartner G. The “critical view of safety (CVS)” cannot be applied—What to do? Strategies to avoid bile duct injuries. European Surgery - Acta Chirurgica Austriaca. 2021;53:99–105.
2. Strasberg SM, Brunt LM. The critical view of safety. Ann Surg. 2017;265:464–5.
3. Singh M, Prasad N. The anatomy of Rouviere’s sulcus as seen during laparoscopic cholecystectomy: A proposed classification. J Minim Access Surg. 2017;13:89–95.
4. Cirocchi R, Panata L, Griffiths EA, Tebala GD, Lancia M, Fedeli P, et al. Injuries during laparoscopic cholecystectomy: A scoping review of the claims and civil action judgements. J Clin Med. 2021;10.
5. Gupta V, Jain G. The R4U Planes for the Zonal Demarcation for Safe Laparoscopic Cholecystectomy. World J Surg. 2021;45:1096–101
6. Dahmane R, Morjane A, Starc A. Anatomy and surgical relevance of Rouviere’s sulcus. The Scientific World Journal. 2013;2013.
7. Al-naser MKH. Rouviere ’ s Sulcus : A Useful Anatomical Landmark for Safe Laparoscopic Cholecystectomy. 2018;158–61.
8. Jha A, Dewan R, Bhaduria K. Importance of Rouviere’s sulcus in laparoscopic cholecystectomy. Ann Afr Med. 2020;19:274–7
9. Kumar A, Shah R, Pandit N, Sah SP, Gupta RK. Anatomy of Rouviere’s Sulcus and Its Association with Complication of Laparoscopic Cholecystectomy. Minim Invasive Surg. 2020;2020:1–7
10. Basukala S, Thapa N, Tamang A, Shah KB, Rayamajhi BB, Ayer D, et al. Rouviere’s sulcus - An anatomical landmark for safe laparoscopic cholecystectomy: A cross-sectional study. Annals of Medicine and Surgery. 2022;75.
11. Bhattarai SR, Acharya P, Yadav PK, Rajbhandari P. Rouviere’s Sulcus: An Important Anatomical Landmark in Laparoscopic Cholecystectomy. Journal of Nepalgunj Medical College. 2022;20:23–6
12. Bajpayee P, Kanaskar N, Vatsalaswamy P, Manivikar PR. Significance of rouviere’s sulcus in hepatobiliary surgery: A cadaveric study. International Journal of Anatomy and Research. 2021;9:8074–8
13. Elfatih O, Omer E, Taha O, Elmukashfi A, Ahmed T, Elsheikh E. Rouviere ’ s Sulcus : Frequency and Types among Patients presented to Wad Madani Teaching Hospital for Laparoscopic Cholecystectomy ; Gezira State ; Sudan. 2024;3–9
14. Pathak R, Mittal L, Chouhan GM, Tripathi A. Rouviere’s Sulcus: A Guide to Safe Laparoscopic Cholecystectomy. Journal of Acute Care Surgery. 2023;13:10–2.
15. Voruganti MR, Mohammed N, Gurrala RC, Chowdary GH, Devarakonda L. Rouviere’s Sulcus: Anatomy and its Clinical Significance in Laparoscopic Cholecystectomy. World Journal of Laparoscopic Surgery. 2023;16:4–7.
16. Ibrahim TM, Yassein TE, Fayed YA, Dawoud ASA. Importance of Rouviere’s sulcus in laparoscopic cholecystectomy. Ann Afr Med. 2020;19:274–7.