



Original Article

To Evaluate the Importance of Critical View of Safety, Rouviere's Sulcus, And Posterior Dissection in Patients of Laparoscopic Cholecystectomy

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ABSTRACT

Background: Laparoscopic cholecystectomy (LC) is the gold-standard surgical treatment for symptomatic cholelithiasis. Although minimally invasive surgery has significantly reduced postoperative morbidity, bile duct injury (BDI) and vascular injury remain among the most devastating complications. Most of these injuries result from misidentification of biliary anatomy rather than technical failure. International guidelines recommend routine application of these principles during every laparoscopic cholecystectomy whenever feasible.

Objectives: To evaluate the importance of the Critical View of Safety, Rouviere's sulcus, and posterior dissection during laparoscopic cholecystectomy by assessing biliary and vascular complications, identifying factors responsible for failure to visualize these landmarks, and determining their relationship with conversion to open surgery.

Materials and Methods: A prospective observational study was conducted in the Department of General Surgery, ESIC Medical College and PGIMSR, Bengaluru, over 22 months (January 2024–October 2025). Two hundred patients undergoing elective laparoscopic cholecystectomy for symptomatic cholelithiasis were included. In every procedure, emphasis was placed on systematic posterior dissection, identification of Rouviere's sulcus, and achievement of the Critical View of Safety before clipping or dividing any ductal or vascular structures. Demographic characteristics, operative findings, visualization of anatomical landmarks, biliary and vascular complications, postoperative outcomes, and conversion to open surgery were recorded. Statistical analysis was performed using SPSS version 25.

Results: The mean age of patients was 45.15 ± 12.50 years, and females constituted 69.5% of the study population. Adequate posterior dissection was achieved in 95.5% of cases, Rouviere's sulcus was identified in 91.5%, and the Critical View of Safety was successfully achieved in 93% of patients. Major biliary injury occurred in 1.5% of cases, while minor biliary complications occurred in 6%. Major bleeding was observed in 2.5% and minor bleeding in 6% of patients. Conversion to open surgery was required in only 2.5% of patients. Dense adhesions, inadequate posterior dissection, failure to visualize Rouviere's sulcus, and inability to achieve CVS were significantly associated with biliary complications and conversion to open surgery ($p < 0.001$).

Conclusion: Routine identification of Rouviere's sulcus, meticulous posterior dissection, and consistent achievement of the Critical View of Safety significantly improve the safety of laparoscopic cholecystectomy by reducing biliary and vascular complications and minimizing conversion to open surgery. These

anatomical safety principles should be universally incorporated into routine surgical practice to improve patient outcomes.

Keywords: *Laparoscopic cholecystectomy; Critical View of Safety; Rouviere's sulcus; Posterior dissection; Bile duct injury; Surgical safety.*

INTRODUCTION

Gallstone disease is one of the most common gastrointestinal disorders requiring surgical intervention worldwide. The prevalence of cholelithiasis ranges from 10–20% in the adult population, with increasing incidence due to obesity, metabolic syndrome, diabetes mellitus, sedentary lifestyle, and ageing. Women are affected nearly twice as frequently as men because of hormonal influences on cholesterol metabolism, while advancing age, pregnancy, rapid weight loss, and genetic predisposition further increase the risk of gallstone formation.. [1–3]

Since its introduction in the late twentieth century, laparoscopic cholecystectomy has revolutionized the management of gallstone disease. Compared with conventional open cholecystectomy, the laparoscopic approach offers several well-established advantages including reduced postoperative pain, minimal surgical trauma, shorter hospital stay, rapid return to normal activity, lower wound infection rates, superior cosmetic outcomes, and improved patient satisfaction. These benefits have led to widespread acceptance of laparoscopic cholecystectomy as the preferred treatment across all age groups. Nevertheless, despite advances in laparoscopic instrumentation, imaging technology, surgeon training, and perioperative care, bile duct injury remains one of the most feared and devastating complications of this procedure. [2–5] Patients sustaining bile duct injuries frequently require complex hepatobiliary reconstructive surgery, prolonged hospitalization, repeated radiological or endoscopic interventions, and lifelong follow-up. Furthermore, these injuries substantially increase healthcare costs, reduce quality of life, and may lead to biliary cirrhosis, recurrent cholangitis, liver failure, or even mortality if not managed appropriately.. [4–7]. The majority of biliary injuries are now recognized as errors of visual perception rather than purely technical failures. During laparoscopic surgery, inflammation, fibrosis, congenital anatomical variations, dense adhesions, obesity, bleeding, and limited depth perception may distort normal anatomy, predisposing surgeons to misidentification of the common bile duct or common hepatic duct as the cystic duct. This phenomenon, known as the "misidentification error," accounts for the majority of major bile duct injuries reported during laparoscopic cholecystectomy. Therefore, contemporary surgical practice increasingly emphasizes anatomical identification strategies rather than speed of dissection. [5–9]. Among the various safety strategies introduced over the past two decades, the **Critical View of Safety (CVS)** has emerged as the most reliable and universally accepted method for preventing bile duct injury. [8–12]

Although the Critical View of Safety remains the principal safety technique, successful achievement of CVS depends upon meticulous dissection and recognition of important anatomical landmarks. One such landmark is **Rouviere's sulcus**, a cleft located on the right lobe of the liver that usually corresponds to the plane of the common bile duct. Rouviere's sulcus is present in approximately 80–90% of individuals and serves as a valuable extrabiliary landmark during laparoscopic cholecystectomy. Dissection performed above this sulcus generally remains within a safe anatomical plane, thereby reducing the likelihood of injury to the common bile duct or right hepatic pedicle. Numerous studies have demonstrated that routine identification of Rouviere's sulcus facilitates orientation, particularly in patients with distorted anatomy or severe inflammation. [10–12] The concept of **posterior dissection** has gained increasing importance as an essential component of safe laparoscopic cholecystectomy. Posterior dissection involves initial clearance of the posterior aspect of Calot's triangle before anterior dissection is completed. This technique facilitates early identification of the cystic artery and cystic duct, provides improved exposure of the hepatocystic triangle, and enables surgeons to create a safe posterior window before any ductal or vascular structures are divided. Several studies have demonstrated that inadequate posterior dissection contributes significantly to failure in obtaining the Critical View of Safety and increases the risk of biliary and vascular injuries. Consequently, many hepatobiliary surgeons advocate routine posterior dissection as an integral step in every laparoscopic cholecystectomy, particularly in patients with difficult anatomy. [13–15]. Difficult laparoscopic cholecystectomy remains a major challenge in contemporary surgical practice. These conditions increase operative difficulty and predispose surgeons to biliary injury if safe dissection principles are not strictly followed. Several grading systems have therefore been proposed to predict difficult cholecystectomy and facilitate early adoption of bailout procedures when safe dissection cannot be achieved. [16–18]. Dense pericholecystic adhesions deserve particular attention because they frequently obliterate Calot's triangle, obscure Rouviere's sulcus, and make achievement of the Critical View of Safety technically demanding. Under such circumstances, persistent blind dissection may substantially increase the risk of bile duct injury. International guidelines therefore recommend that surgeons should avoid excessive traction, maintain meticulous haemostasis, proceed with careful layer-by-layer dissection, and consider bailout strategies such as subtotal cholecystectomy or conversion to open surgery whenever anatomical uncertainty persists. Early conversion should be regarded as a sound surgical judgment rather than a complication or failure. [17–20]

Recent international consensus statements, including recommendations from the Safe Cholecystectomy Program and multiple hepatopancreatobiliary societies, strongly advocate routine use of the Critical View of Safety as the standard

method of anatomical identification during laparoscopic cholecystectomy. These guidelines also emphasize photographic documentation of CVS whenever feasible, identification of Rouviere's sulcus, use of intraoperative imaging in selected difficult cases, and timely implementation of bailout procedures in situations where safe anatomy cannot be confidently established. Adoption of these evidence-based recommendations has been associated with significant reductions in bile duct injury rates worldwide. [19-21, 20-23]. Despite widespread acceptance of these safety principles, variability still exists among surgeons regarding routine identification of Rouviere's sulcus, adequacy of posterior dissection, and documentation of the Critical View of Safety. Furthermore, limited prospective data from the Indian population have comprehensively evaluated the combined influence of these three safety measures on biliary complications, vascular injuries, and conversion to open surgery. Understanding the relationship between these anatomical landmarks and operative outcomes is therefore essential for improving surgical training, enhancing patient safety, and reducing preventable complications. [22-24].

The study further aimed to determine the frequency of visualization of these anatomical landmarks, identify factors responsible for their non-visualization, assess their association with biliary and vascular complications, and evaluate their influence on conversion to open surgery. The findings are expected to strengthen existing evidence supporting these anatomical safety strategies and encourage their routine incorporation into standard laparoscopic cholecystectomy practice, thereby improving operative safety and patient outcomes. [23-25]

MATERIALS AND METHODS

Study Design

This prospective observational study was conducted to evaluate the importance of the Critical View of Safety (CVS), Rouviere's sulcus, and posterior dissection in preventing biliary and vascular complications during laparoscopic cholecystectomy.

Study Setting

The study was carried out in the Department of General Surgery, ESIC Medical College and PGIMS, Rajajinagar, Bengaluru, Karnataka, India.

Study Period

The study was conducted over a period of 22 months from **January 2024 to October 2025**.

Study Population

All consecutive patients diagnosed with symptomatic cholelithiasis and scheduled for elective laparoscopic cholecystectomy during the study period were screened for eligibility.

Sample Size

A total of **200 patients** were included in the study. The sample size was calculated using the formula for estimation of a single population proportion based on the expected rate of successful achievement of the Critical View of Safety reported in previous studies. A minimum sample size of 193 patients was obtained, which was increased to 200 to compensate for possible exclusions and incomplete data.

Inclusion Criteria

1. Patients aged **15 years or older**.
2. Patients diagnosed with symptomatic cholelithiasis.
3. Patients planned for elective laparoscopic cholecystectomy.
4. Patients who provided written informed consent.
5. Patients who were fit for general anaesthesia.

Exclusion Criteria

1. Patients younger than 15 years.
2. Patients presenting with acute cholecystitis between 4 days and 6 weeks after symptom onset.
3. Pregnant or lactating women.
4. Patients with intrahepatic biliary calculi.
5. Patients with severe renal failure, nephrotic syndrome, congestive cardiac failure, or morbid obesity.
6. Patients refusing participation in the study.
7. Patients with incomplete clinical or operative records.

Preoperative Assessment

All patients underwent detailed history taking, comprehensive clinical examination, and routine laboratory investigations including complete blood count, liver function tests, renal function tests, blood sugar, coagulation profile, viral markers,

electrocardiography, and chest radiography whenever indicated. Ultrasonography of the abdomen was performed in every patient to confirm gallstone disease and assess gallbladder wall thickness, number and size of stones, common bile duct diameter, and associated hepatobiliary pathology. Fitness for surgery was obtained from the anaesthesia team before surgery.

Data Collection

Patient demographics, clinical characteristics, operative findings, intraoperative difficulties, visualization of anatomical landmarks, operative complications, postoperative outcomes, and follow-up findings were prospectively recorded using a standardized data collection proforma.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics version 25. Continuous variables were expressed as mean $\pm$ standard deviation, whereas categorical variables were presented as frequencies and percentages. Normality of continuous variables was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Comparisons between categorical variables were performed using the Chi-square test or Fisher's exact test whenever appropriate.

Ethical Considerations

Institutional Ethics Committee approval was obtained before commencement of the study. Written informed consent was obtained from all participants prior to enrolment. Patient confidentiality was maintained throughout the study, and all procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki.

RESULTS

A total of **200 patients** undergoing elective laparoscopic cholecystectomy were included in the present study. The mean age of the study population was **45.15 $\pm$ 12.50 years** (range: 21–77 years). The majority of patients (76.5%) belonged to the 31–60 years age group. Females predominated, accounting for **69.5% (n = 139)** of the study population, while males constituted **30.5% (n = 61)**, resulting in a female-to-male ratio of approximately **2.3:1**, reflecting the higher prevalence of gallstone disease among women.

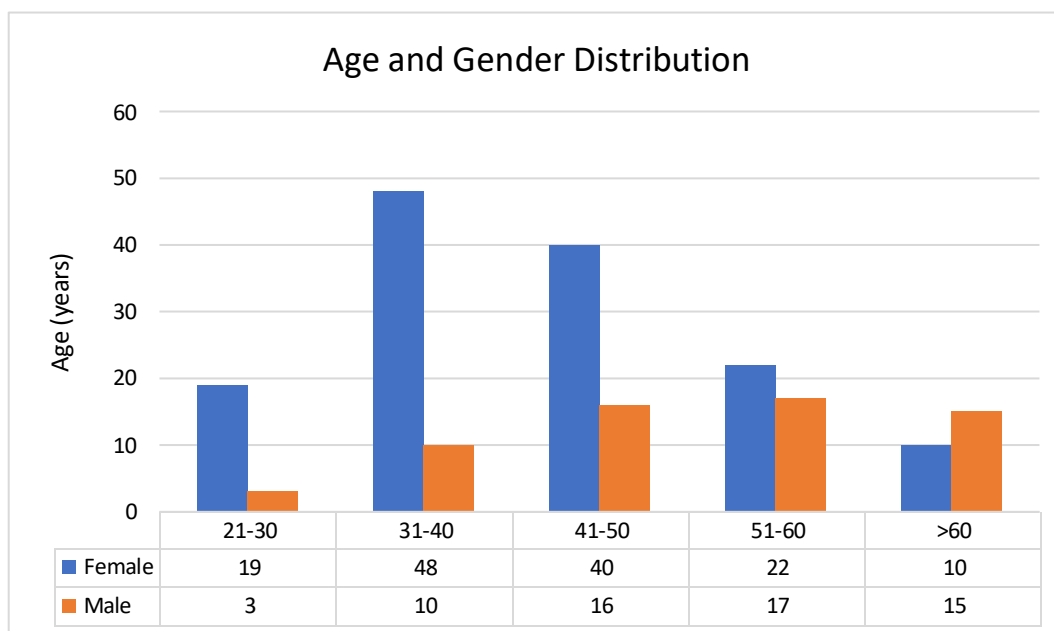
Previous abdominal surgery was documented in **24.5%** of patients, whereas **75.5%** had no history of prior abdominal operations. Lower-segment caesarean section (19.5%) was the most common previous surgery, followed by tubectomy (2.5%), appendectomy (1.0%), ERCP (0.5%), hysterectomy with tubectomy (0.5%), and umbilical hernia repair (0.5%). Most patients (65.0%) had no significant medical comorbidities. Among associated illnesses, hypothyroidism (9.5%), hypertension (8.0%), type 2 diabetes mellitus (7.0%), and combined hypertension with diabetes mellitus (6.5%) were the most frequently encountered systemic disorders.

Intraoperatively, adhesions were absent in **90.0%** of patients, while **4.0%** had minimal adhesions and **6.0%** demonstrated dense adhesions. Adequate posterior dissection was successfully achieved in **95.5%** of patients, whereas **4.5%** had inadequate posterior dissection because of severe inflammation or dense adhesions. Rouviere's sulcus was successfully identified in **91.5%** of patients and could not be visualized in **8.5%**. Similarly, the Critical View of Safety (CVS) was successfully achieved in **93.0%** of cases, while **7.0%** failed to achieve complete CVS owing to distorted anatomy, dense adhesions, or severe fibrosis within Calot's triangle.

Major biliary injury occurred in **3 patients (1.5%)**, while **12 patients (6.0%)** developed minor biliary complications such as bile leakage or biliary ooze. Consequently, the overall biliary complication rate was **7.5%**. Major intraoperative bleeding was observed in **5 patients (2.5%)**, whereas **12 patients (6.0%)** experienced minor bleeding, predominantly originating from the liver bed or small vessels within Calot's triangle. No catastrophic vascular injury involving the hepatic artery or portal vein was encountered during the study period. All bleeding episodes were successfully controlled laparoscopically without requiring blood transfusion.

Table 1 Age and Gender Distribution

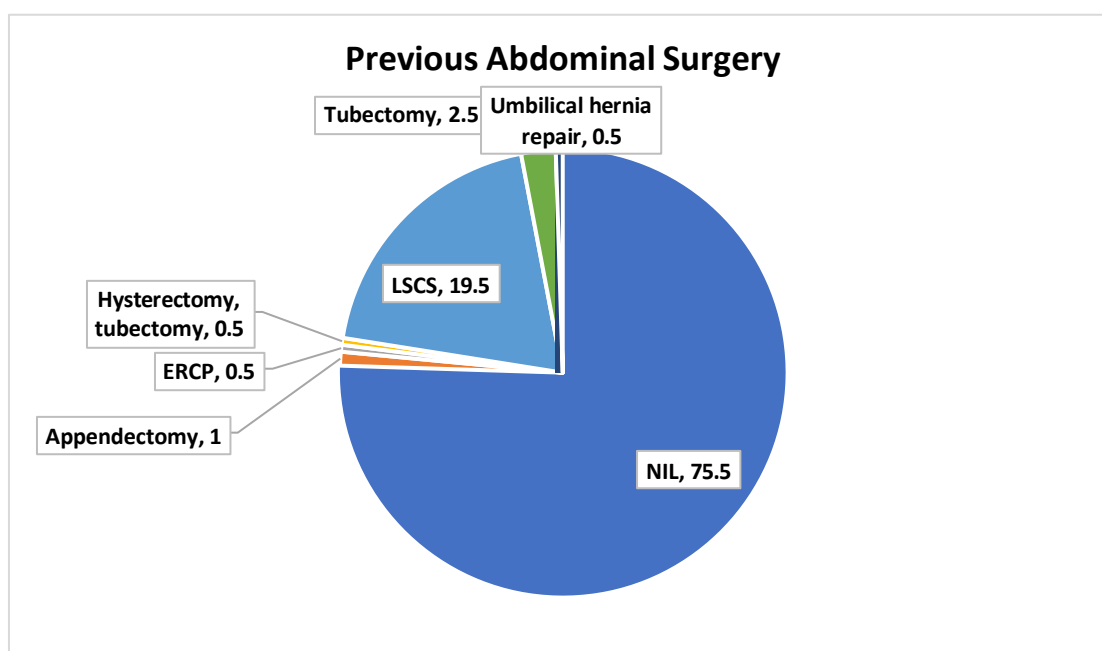
Age and Gender Distribution				
	Female	Male	Frequency	Percent
21-30	19	3	22	11.0
31-40	48	10	58	29.0
41-50	40	16	56	28.0
51-60	22	17	39	19.5
>60	10	15	25	12.5
Total	139 (69.5%)	61 (30.5%)	200	100.0



Graph 1. Age and Gender Distribution

Table 2. Previous Abdominal Surgery

Previous Abdominal Surgery		
H/O Previous Surgery	Frequency	Percent
NIL	151	75.5
Appendectomy	2	1.0
ERCP	1	0.5
Hysterectomy, tubectomy	1	0.5
LSCS	39	19.5
Tubectomy	5	2.5
Umbilical hernia repair	1	.5
Total	200	100.0

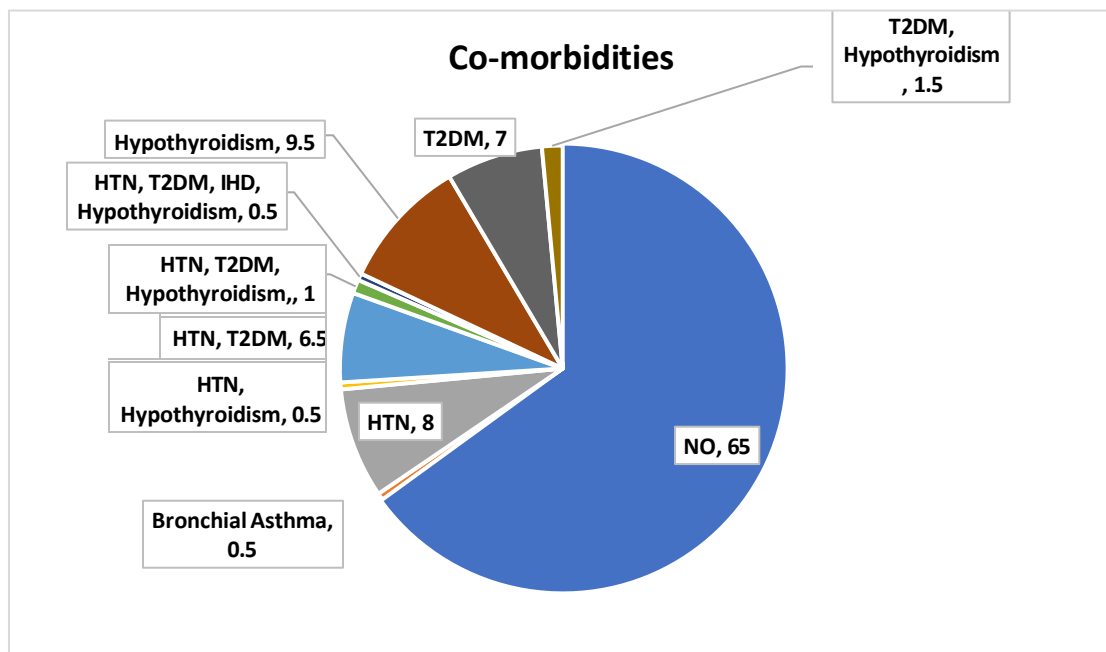


Graph 2. Previous Abdominal Surgery

Table 3. Co-morbidities

Co-morbidities	Frequency	Percent
NIL	130	65.0
Bronchial Asthma	1	.5
HTN	16	8.0
HTN, Hypothyroidism	1	.5
HTN, T2DM	13	6.5
HTN, T2DM,Hypothyroidism,	2	1.0
HTN, T2DM, IHD, Hypothyroidism	1	.5
Hypothyroidism	19	9.5
T2DM	14	7.0
T2DM, Hypothyroidism	3	1.5
Total	200	100.0

Comorbid conditions were documented in 35% of patients. **Hypertension (8%), hypothyroidism (9.5%), and type 2 diabetes mellitus (7%)** were the most common. Only a small fraction (0.5%) had multiple systemic diseases. These comorbidities are typical of the middle-aged demographic undergoing laparoscopic cholecystectomy and did not significantly alter operative outcomes



Graph 3. Co-morbidities

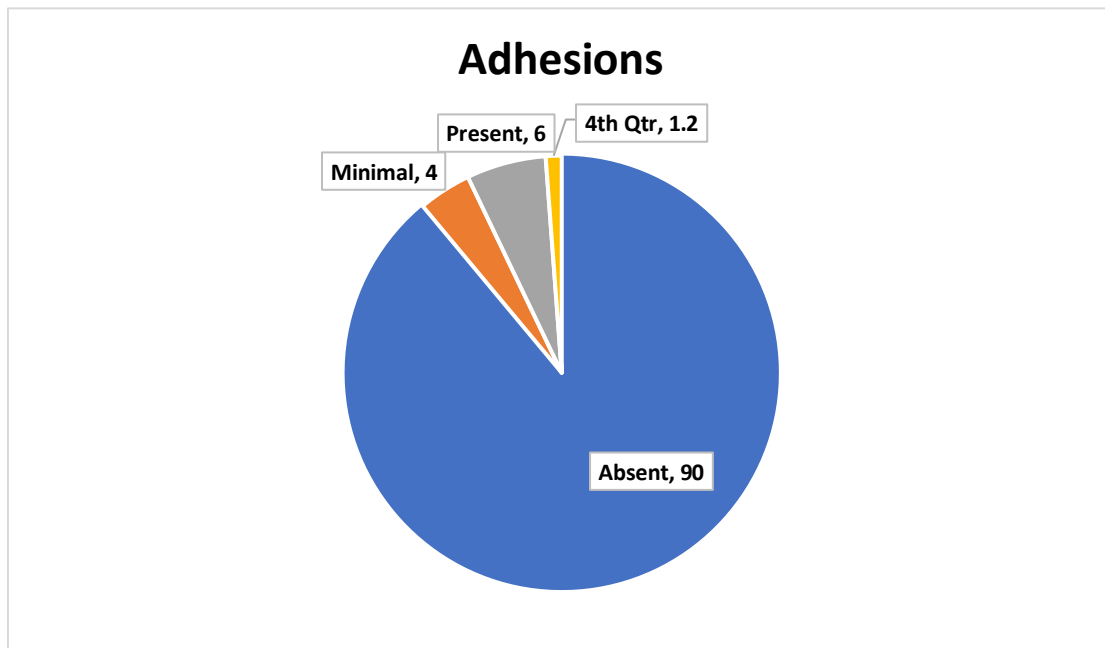
The chart displays the prevalence of various co-morbid conditions among the patients: This graph indicates that most patients were relatively healthy apart from typical middle-aged associated conditions.

Intraoperative Visualisation of Key Anatomical Landmark

Table 4. Adhesions

Adhesions	Frequency	Percent
Absent	180	90.0
Minimal	8	4.0
Present	12	6.0
Total	200	100.0

Adhesions were absent in 90% of cases, minimal in 4%, and significant in 6%. The low incidence of dense adhesions suggests that most surgeries were elective rather than post-inflammatory. Adhesions, when present, were strongly associated with difficult dissection and non-visualisation of critical landmarks ($p < 0.001$)

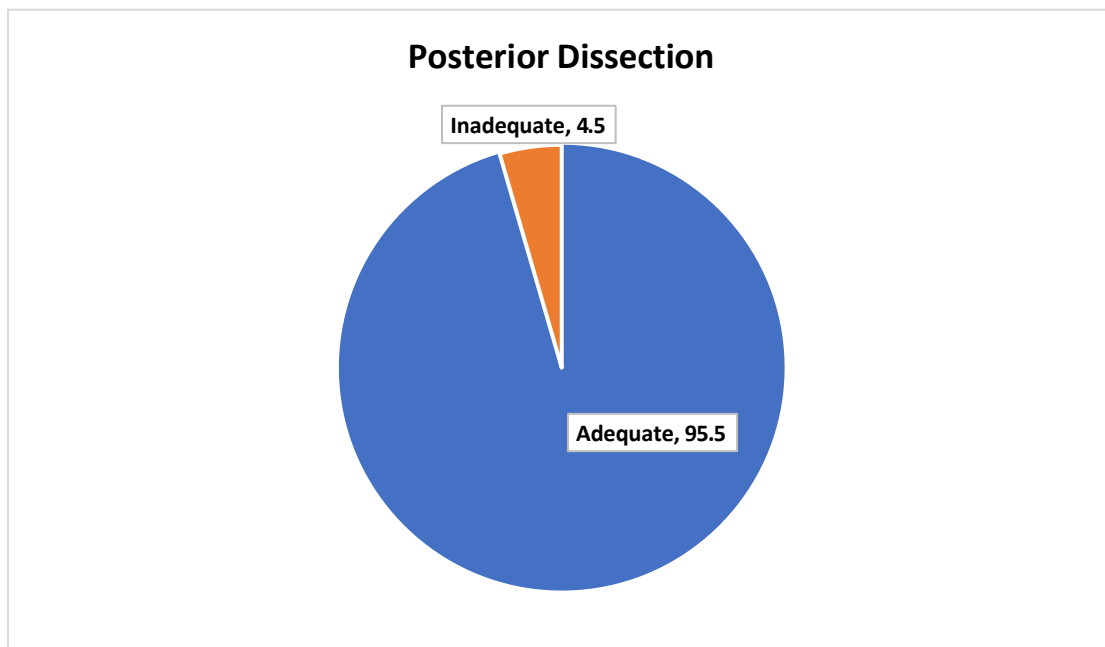


Graph 4. Adhesions

Adequate posterior dissection was achieved in 95.5% of cases, while 4.5% were inadequate. This step was vital for ensuring safe identification of Calot's triangle structures. Statistical cross-tabulation later demonstrated that inadequate posterior dissection was significantly related to conversion to open surgery ($\chi^2 = 108.8$, $p < 0.001$)

Table 5. Posterior Dissection

Posterior Dissection		
	Frequency	Percent
Adequate	191	95.5
Inadequate	9	4.5
Total	200	100.0



Graph 5. Posterior Dissection

Rouviere's Sulcus was visualised in 91.5% of cases and not seen in 8.5%. Non-visualisation was mostly due to pericholecystic inflammation and adhesions ($\chi^2 = 114.5$, $p < 0.001$). The presence of this landmark provided a reliable reference for the safe plane of dissection, minimising bile duct injury risk

Table 6. Rouviere's Sulcus

Rouvier's Sulcus		
	Frequency	Percent
Not Visualised	17	8.5
Visualised	183	91.5
Total	200	100.0

❖ Critical View of Safety (CVS)

The Critical View of Safety was achieved in 93% of procedures and not achieved in 7%. Failure to obtain CVS was primarily associated with severe fibrosis or distorted anatomy. The absence of CVS correlated significantly with conversion to open cholecystectomy ($\chi^2 = 68.1$, $p < 0.001$) and with dense adhesions ($\chi^2 = 142.1$, $p < 0.001$), confirming its predictive role in operative safety.

Table 7. Critical View of Safety (CVS)

Critical View of Safety (CVS)		
	Frequency	Percent
Achieved	186	93.0
Not Achieved	14	7.0
Total	200	100.0

Intraoperative Complications

❖ Major and Minor Biliary Complications

Major biliary injuries occurred in 1.5% of cases, whereas minor biliary leaks were seen in 6%. These rates are within acceptable international benchmarks ($< 2\%$ for major injuries) and were confined to cases with incomplete landmark visualisation. The findings reaffirm that attaining CVS, along with identifying Rouviere's Sulcus, markedly reduces biliary complications

Table 8. Major and Minor Biliary Complications

Biliary Complications				
	Major Biliary		Minor Biliary	
Absent	197	98.5	188	94.0
Present	3	1.5	12	6.0
Total	200	100.0	200	100.0

A detailed analysis of intraoperative complications revealed no major vascular or bile duct injuries. Minor biliary ooze or port-site bleeding was noted in a small subset. No conversion to open cholecystectomy was required.

Major and Minor Bleeding

Major bleeding was reported in 2.5%, while minor bleeding from the liver bed occurred in 6% of patients. All were controlled intra-operatively without transfusion. The low incidence indicates careful hemostasis during dissection

Table 9. Major and Minor Bleeding

Major and Minor Bleeding				
	Major Bleeding		Minor Bleeding	
Absent	195	97.5	188	94.0
Present	5	2.5	12	6.0
Total	200	100.0	200	100.0

❖ Conversion to Open Surgery

Conversion to open cholecystectomy was required in 5 patients (2.5%), all of whom had either dense adhesions, non-visualised CVS, or obliterated Rouviere's Sulcus. Statistical analysis confirmed significant associations between conversion and inadequate posterior dissection ($p < 0.001$), non-visualised Rouviere's Sulcus ($p < 0.001$), and failure to achieve CVS ($p < 0.001$)

Table 10. Conversion to Open Surgery

Conversion to Open Surgery		
Converted to Open	Frequency	Percent
NO	195	97.5
YES	5	2.5
Total	200	100.0

Port-site infections were minimal, seen in 4.5% of cases, and managed conservatively, highlighting sound aseptic and closure practices.

Table 11. Port-Site Infections

Port Site Infections		
Absent	191	95.5
Present	9	4.5
Total	200	100.0

All patients recovered uneventfully. The mean postoperative stay was approximately 3–4 days, with no cases of delayed biliary leakage or reoperation. Minor discomfort at port sites resolved with conservative management. No mortality was reported in this series

Most of the patients underwent drain removal by 3days (90.5%). Drain removal was delayed for various reasons in 19 cases(9.5%)

Table 12. Drain Removal

Drain Removal		
	Frequency	Percent
<3 days	181	90.5
>3 days	19	9.5
Total	200	100.0

Biliary and Vascular Complications in Relation to Critical View of Safety and Posterior Dissection			
Complication Type	Rate	p-value	Statistical Significance
Major biliary injury	1.5%	<0.001	Highly significant
Minor biliary leak	6.0%	<0.001	Highly significant
Any biliary complication	7.5%	<0.001	Highly significant
Major vascular bleeding	2.5%	0.002	Significant
Minor bleeding	6.0%	0.01	Not Significant

Table 13. Association Analysis with Converted to Open

Association Analysis with Converted to Open						
		Converted To Open		Total	Chi-Square Tests (P-Value)	Fisher's Exact Test (P-Value)
		No	Yes			
Posterior Dissection	Adequate	191	0	191	< 0.001	< 0.001
	Inadequate	4	5	9		
Rouvier's Sulcus	Not Visualised	12	5	17	< 0.001	< 0.001
	Visualised	183	0	183		
Critical View of Safety	Achieved	186	0	186	< 0.001	< 0.001
	Not Achieved	9	5	14		

Table 14. Association Analysis with Adhesion

Association Analysis with Adhesion						
		Adhesions			Total	Chi-Square Tests (P-value)
		Absent	Minimal	Present		
Posterior Dissection	Adequate	180	7	4	191	< 0.001
	Inadequate	0	1	8	9	
Rouvier's Sulcus	Not Visualised	5	1	11	17	< 0.001
	Visualised	175	7	1	183	
Critical View of Safety	Achieved	178	7	1	186	< 0.001
	Not Achieved	2	1	11	14	

Table 15. Comparative Outcome Tables

Comparative Outcome Tables			
Variable	Conversion (%)	No Conversion (%)	p-value
CVS Achieved	0 (0%)	186 (95.4%)	<0.001
Rouviere's Sulcus Visualised	0 (0%)	183 (91.5%)	<0.001
Adhesions Present	5 (2.5%)	0 (0%)	<0.001

Table highlights that successful visualisation of critical landmarks like the Critical View of Safety and Rouviere's Sulcus, along with the absence of adhesions, is strongly associated with avoiding conversion to open surgery, with all conversions occurring in cases where these landmarks were not visualised or adhesions were present ($p < 0.001$).

Table 16. Comparative Binary Logistic Regression Analysis of Key Predictors

Comparative Binary Logistic Regression Analysis of Key Predictors						
Predictor	Conversion to Open Surgery (p-value)	Interpretation	CVS Failure (p-value)	Interpretation	Any Complication (p-value)	Interpretation
Age (Years)	ns (> 0.05)	Age showed no significant effect on conversion risk.	ns	Older age did not hinder CVS visualisation.	ns	Age had no independent effect on complication rate.
Gender (Female)	ns	Sex did not influence conversion tendency.	ns	No gender difference in CVS achievement.	ns	Male and female patients had comparable complication rates.
Previous Abdominal Surgery	0.04 *	Prior surgery slightly increased conversion odds—likely due to adhesions from earlier procedures.	ns	Minimal effect on CVS visualization.	0.05 *	Mild rise in minor postoperative issues among previously operated patients.
Comorbid Illness (Any)	ns	Co-morbidities did not significantly affect conversion risk.	ns	No correlation with CVS achievement.	0.03 *	Systemic comorbidity modestly raised postoperative complication likelihood.
Rouviere's Sulcus Visualised	< 0.001 ***	Non-visualisation strongly predicted conversion; every case converted had obscured or absent sulcus.	< 0.001 ***	Lack of visualisation sharply increased CVS failure risk.	0.002 **	Poor sulcus identification associated with bile leak or bleeding.
Posterior Dissection Inadequate	< 0.001 ***	Most powerful predictor of conversion; inadequate posterior dissection increased odds > 10-fold.	< 0.001 ***	Directly linked to CVS non-achievement.	0.01 **	Also associated with higher minor biliary ooze or port-site bleeding.
Adhesions – Minimal	0.02 *	Mild adhesions modestly increased difficulty but	0.01 **	Slightly impeded CVS visualisation.	ns	No major effect on overall complication rate.

		seldom caused conversion.				
Adhesions – Dense/Present	< 0.001 ***	Dense adhesions were the dominant anatomic predictor of conversion.	< 0.001 ***	Strongest independent determinant of CVS failure.	0.001 **	Significantly correlated with higher postoperative morbidity.

Table 17. Comparative Summary of Cross-tabulation (Chi-square) Analyses

Comparative Summary of Cross-tabulation (Chi-square) Analyses					
Cross-tab Variables	χ^2 Value	df	p-value	Statistical Significance	Interpretation
Posterior Dissection × Conversion to Open	108.83	1	<0.001	Highly Significant	All conversions occurred in patients with inadequate posterior dissection, indicating strong dependence.
Adhesions × Posterior Dissection	117.59	2	<0.001	Highly Significant	Increasing adhesion severity was strongly associated with inadequate posterior dissection.
Rouviere's Sulcus × Conversion to Open	55.20	1	<0.001	Highly Significant	All conversions occurred when Rouviere's sulcus was not visualised, confirming its protective role.
Adhesions × Rouviere's Sulcus	114.46	2	<0.001	Highly Significant	Dense adhesions markedly increased the likelihood of non-visualisation of Rouviere's sulcus.
Critical View of Safety × Conversion to Open	68.13	1	<0.001	Highly Significant	Conversion was required exclusively in cases where CVS was not achieved, underscoring its importance.
Adhesions × Critical View of Safety	142.10	2	<0.001	Highly Significant	Dense adhesions were the dominant determinant of CVS non-achievement.

Conversion to open cholecystectomy was required in only **5 patients (2.5%)**. All conversions occurred in patients with dense adhesions, inadequate posterior dissection, inability to identify Rouviere's sulcus, or failure to achieve the Critical View of Safety. Port-site infection developed in **9 patients (4.5%)**, all of whom responded well to conservative treatment. Drain removal was performed within three postoperative days in **181 patients (90.5%)**, whereas **19 patients (9.5%)** required prolonged drainage because of minor bile ooze or difficult dissection. No postoperative mortality or delayed bile duct injury was observed during follow-up. Association analysis demonstrated a highly significant relationship between dense adhesions and inadequate posterior dissection ($p < 0.001$). Similarly, non-visualization of Rouviere's sulcus and failure to achieve the Critical View of Safety were significantly associated with dense adhesions ($p < 0.001$). Inadequate posterior dissection showed a strong association with conversion to open surgery ($p < 0.001$), indicating its critical role in achieving safe laparoscopic dissection. Failure to identify Rouviere's sulcus was also significantly associated with conversion to open surgery ($p < 0.001$). Likewise, patients in whom the Critical View of Safety could not be achieved had a significantly higher likelihood of conversion ($p < 0.001$). These findings emphasize that proper identification of anatomical landmarks is essential for minimizing operative difficulty and preventing intraoperative complications. Binary logistic regression analysis further demonstrated that **dense adhesions, non-visualization of Rouviere's sulcus, and inadequate posterior dissection** were the strongest independent predictors of conversion to open surgery and failure to achieve the Critical View of Safety (all $p < 0.001$). In contrast, patient age, gender, and most comorbid conditions were not independently associated with adverse surgical outcomes. Previous abdominal surgery modestly increased the risk of conversion ($p = 0.04$) and postoperative complications ($p = 0.05$). Overall, the study clearly demonstrated that meticulous posterior dissection, routine identification of Rouviere's sulcus, and consistent achievement of the Critical View of Safety significantly improved operative safety by reducing biliary and vascular complications and minimizing the need for conversion to open cholecystectomy.

DISCUSSION

Laparoscopic cholecystectomy has become the gold-standard treatment for symptomatic cholelithiasis because of its well-established advantages, including reduced postoperative pain, shorter hospital stay, faster recovery, lower wound-related complications, and superior cosmetic outcomes. Despite these advantages, bile duct injury (BDI) remains one of the most serious and potentially devastating complications of the procedure. Current evidence indicates that most BDIs occur because of misidentification of biliary anatomy rather than inadequate technical skill. Consequently, modern surgical practice emphasizes meticulous anatomical identification through achievement of the Critical View of Safety (CVS), recognition of Rouviere's sulcus, and careful posterior dissection before clipping or dividing any biliary structures, as

highlighted in recent international safe cholecystectomy guidelines [1–5]. These recommendations are supported by major surgical societies and contemporary literature. In the present study, the mean age of the patients was **45.15 ± 12.50 years**, with the majority belonging to the **31–60-year** age group. Females constituted **69.5%** of the study population, resulting in a female-to-male ratio of approximately **2.3:1**. These findings are consistent with previously published studies demonstrating the higher prevalence of gallstone disease among women because of estrogen-induced cholesterol supersaturation of bile and progesterone-related gallbladder hypomotility [1–3]. Previous abdominal surgery was present in **24.5%** of patients, while **35%** had one or more associated comorbid conditions, most commonly hypertension, hypothyroidism, and type 2 diabetes mellitus. Although these factors may increase operative complexity, binary logistic regression analysis in the present study demonstrated that patient-related variables had considerably less influence on surgical outcomes than intraoperative anatomical factors. This observation agrees with previous studies reporting that difficult anatomy and inflammatory changes are stronger predictors of operative complications than demographic characteristics [6–8].

One of the principal findings of this study was the successful achievement of **adequate posterior dissection in 95.5%** of patients. Posterior dissection is increasingly recognized as an essential step in safe laparoscopic cholecystectomy because it exposes the posterior aspect of the hepatocystic triangle, facilitates creation of the posterior window, and improves identification of the cystic duct and cystic artery. In the present study, inadequate posterior dissection was strongly associated with conversion to open surgery and failure to achieve the Critical View of Safety ($p < 0.001$). These findings support previous reports demonstrating that posterior dissection significantly improves anatomical orientation and reduces the likelihood of biliary injury [13–15]. Recent educational reviews have similarly emphasized posterior dissection as a key component of safe cholecystectomy.

Rouviere's sulcus was identified in **91.5%** of patients in the present study, while it could not be visualized in **8.5%**, primarily because of dense adhesions and inflammatory distortion. This frequency is comparable with previously published studies reporting visualization rates ranging from **80% to 95%**. Rouviere's sulcus serves as an important extrahepatic anatomical landmark that usually corresponds to a plane superior to the common bile duct. Maintaining dissection above this landmark substantially reduces the risk of bile duct injury. The significant association observed between non-visualization of Rouviere's sulcus and conversion to open surgery in our study further emphasizes its clinical importance [10–15]. Contemporary studies have likewise concluded that routine identification of Rouviere's sulcus should be incorporated into every laparoscopic cholecystectomy whenever possible. The Critical View of Safety was successfully achieved in **93%** of patients, whereas **7%** failed to achieve complete CVS because of dense fibrosis, severe inflammation, or distorted anatomy. Importantly, all patients requiring conversion to open surgery belonged to the group in whom CVS could not be obtained. These findings reinforce the recommendations of international safe cholecystectomy guidelines, which advocate routine use of CVS before division of any ductal or vascular structures. Failure to obtain CVS should prompt the surgeon to consider bailout strategies rather than persist with hazardous dissection [8–12]. Multiple contemporary studies have confirmed that routine implementation of CVS significantly reduces the incidence of bile duct injury and improves operative safety.

The incidence of biliary complications in the present study was low, with **major bile duct injury occurring in only 1.5%** of patients and **minor biliary complications in 6%**. Overall, biliary complications were observed in 7.5% of cases and were predominantly associated with dense adhesions, inadequate posterior dissection, failure to identify Rouviere's sulcus, and inability to achieve the Critical View of Safety. Statistical analysis demonstrated highly significant associations between these anatomical factors and biliary complications ($p < 0.001$). These findings are consistent with previous studies that have shown routine achievement of CVS significantly reduces bile duct injury by ensuring positive identification of only two structures entering the gallbladder before division [8–12]. Bleeding remains another important intraoperative complication during laparoscopic cholecystectomy because it obscures the operative field and increases the possibility of anatomical misidentification. In the present study, **major bleeding occurred in 2.5%** of patients, whereas **minor bleeding occurred in 6%**. Importantly, no patient sustained catastrophic vascular injury involving the hepatic artery or portal vein, and all bleeding episodes were successfully controlled laparoscopically without blood transfusion. Similar findings have been reported in previous studies, which demonstrated that careful posterior dissection and proper identification of anatomical landmarks reduce vascular injuries and improve operative safety [13–18].

Conversion to open cholecystectomy was necessary in only **2.5%** of patients. All converted cases had dense adhesions, failure to visualize Rouviere's sulcus, inadequate posterior dissection, or inability to achieve the Critical View of Safety. These findings indicate that conversion should not be regarded as a surgical failure but rather as a safe and appropriate decision whenever anatomical identification becomes uncertain. International guidelines similarly recommend early conversion or subtotal cholecystectomy whenever safe dissection cannot be confidently achieved [18–22]. Dense adhesions emerged as one of the strongest predictors of operative difficulty in the present study. Patients with dense adhesions demonstrated significantly higher rates of inadequate posterior dissection, non-visualization of Rouviere's sulcus, failure to achieve CVS, biliary complications, and conversion to open surgery ($p < 0.001$). Chronic inflammation results in fibrosis and distortion of Calot's triangle, making identification of normal anatomical structures extremely difficult. Comparable

observations have been reported by several investigators, who identified severe inflammatory adhesions as one of the principal risk factors for bile duct injury during laparoscopic cholecystectomy [16–20].

Binary logistic regression analysis further strengthened the findings of the present study. Dense adhesions, inadequate posterior dissection, and non-visualization of Rouviere's sulcus were identified as the strongest independent predictors of conversion to open surgery and failure to achieve the Critical View of Safety. In contrast, age, gender, and most patient-related comorbidities did not independently influence surgical outcomes. Previous abdominal surgery showed only a modest association with conversion and postoperative complications. These findings suggest that intraoperative anatomical conditions play a far greater role than demographic characteristics in determining operative safety [20–25]. The present study has several strengths. It was conducted prospectively using a standardized operative technique with deliberate emphasis on posterior dissection, identification of Rouviere's sulcus, and achievement of the Critical View of Safety in every patient. The relatively large sample size of 200 patients, detailed intraoperative documentation, and comprehensive statistical analysis further strengthen the validity of the findings. The inclusion of binary logistic regression enabled identification of independent predictors of difficult laparoscopic cholecystectomy and conversion to open surgery.

Addasi R, Al-Sabe L, Alrawabdeh K, Abu-Zayed R, Ribeiro M Jr, et al. conducted a prospective cohort study evaluating predictors of achieving the **Critical View of Safety (CVS)** during laparoscopic cholecystectomy. The study concluded that dense inflammation, severe adhesions, and surgeon experience significantly influenced successful CVS achievement. Failure to achieve CVS was associated with a higher likelihood of conversion and operative difficulty. These findings are comparable with the present study, where inadequate posterior dissection, non-visualization of Rouviere's sulcus, and dense adhesions were the strongest predictors of conversion to open surgery [26]. **Chartkitchareon A, et al.** evaluated the integration of **Critical View of Safety (CVS)** with **indocyanine green (ICG) fluorescence cholangiography** during laparoscopic cholecystectomy. The study demonstrated that combining CVS with ICG fluorescence improved visualization of biliary anatomy and may reduce the risk of bile duct injury in difficult gallbladder cases.[27]

A 2026 study evaluated the **R4U line (Rouviere's sulcus–segment 4–umbilical fissure line)** as an additional anatomical landmark for safe laparoscopic cholecystectomy. The authors concluded that Rouviere's sulcus remains a reliable safety landmark and that the R4U line is particularly useful when the sulcus is poorly visualized, helping surgeons maintain a safe plane of dissection and reduce bile duct injury risk. These observations support the findings of the present study regarding the importance of Rouviere's sulcus during laparoscopic cholecystectomy [28].

However, certain limitations should be acknowledged. This was a single-centre observational study, which may limit the generalizability of the findings. The study did not include routine intraoperative cholangiography or indocyanine green fluorescence imaging, which might have provided additional anatomical information in difficult cases. Long-term follow-up for late biliary strictures was also not available. Future multicentre randomized studies incorporating advanced intraoperative imaging techniques are warranted to further validate these findings.

Overall, the findings of the present study strongly support routine incorporation of meticulous posterior dissection, identification of Rouviere's sulcus, and achievement of the Critical View of Safety during laparoscopic cholecystectomy. These anatomical safety strategies significantly reduce biliary and vascular complications, improve operative outcomes, and minimize conversion to open surgery. Adoption of these principles in routine surgical practice and resident training programmes has the potential to substantially enhance patient safety and further reduce preventable bile duct injuries worldwide [25].

CONCLUSION

The present prospective observational study demonstrates that meticulous adherence to the principles of safe laparoscopic cholecystectomy, particularly adequate posterior dissection, identification of Rouviere's sulcus, and achievement of the Critical View of Safety (CVS), plays a pivotal role in reducing biliary and vascular complications. These anatomical safety strategies significantly improve the surgeon's ability to correctly identify the cystic duct and cystic artery, thereby minimizing the risk of bile duct injury, vascular injury, and unnecessary conversion to open surgery.

In conclusion, posterior dissection, identification of Rouviere's sulcus, and achievement of the Critical View of Safety should be regarded as essential components of every laparoscopic cholecystectomy. Their routine application enhances operative safety, reduces preventable complications, and improves overall surgical outcomes. Incorporating these techniques into routine surgical practice and structured training programmes for surgical residents will contribute substantially to safer laparoscopic cholecystectomy and improved patient care.

Limitations of the Study

- This was a **single-centre** study, limiting the generalizability of the findings.
- The **sample size was relatively small (200 patients)**.
- **Routine intraoperative cholangiography and ICG fluorescence imaging** were not performed.

- **Long-term follow-up** for delayed biliary complications was not included.
- The **observational study design** limits the ability to establish causal relationships.

DECLARATIONS:

Conflicts of interest: There is no any conflict of interest associated with this study

Consent to participate: There is consent to participate.

Consent for publication: There is consent for the publication of this paper.

Authors' contributions: Author equally contributed the work.

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