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Original Research Article

Comparison of loop ligation and clip ligation of the cystic duct during laparoscopic cholecystectomy: a prospective study

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ABSTRACT

Background: Laparoscopic cholecystectomy is the gold standard treatment for symptomatic cholelithiasis and cholecystitis. Cystic duct stump leakage remains an important and potentially preventable cause of postoperative bile leak. This study compared loop ligature closure and clip closure of the cystic duct with respect to postoperative bile leak following laparoscopic cholecystectomy.
Methods: A prospective comparative study was conducted at Stanley Medical College Hospital, Chennai, between August 2023 and September 2025. One hundred patients with symptomatic cholelithiasis or acute cholecystitis undergoing elective laparoscopic cholecystectomy were enrolled. Patients were allocated to either Group A (loop ligature closure) or Group B (clip closure) of the cystic duct. Postoperative monitoring for bile leak was performed through clinical assessment and biochemical evaluation. Patients were followed up at 1 and 3 months.
Results: Three patients required conversion to open cholecystectomy and were excluded from the analysis. Among the remaining 97 patients, bile leak occurred in 1 of 47 patients (2.1%) in the loop closure group and 2 of 49 patients (4.1%) in the clip closure group, with no statistically significant difference between the groups. Both techniques provided effective cystic duct occlusion. Loop ligature closure was associated with lower material cost compared with metallic clips. No late complications were observed during follow-up.
Conclusion: Loop ligature closure and clip closure are both safe and effective methods for cystic duct occlusion during laparoscopic cholecystectomy. Loop ligature closure represents a practical and cost-effective alternative to metallic clips without increasing the risk of postoperative bile leak.

Keywords: Laparoscopic cholecystectomy, Cystic duct ligation, Postoperative bile leak, Endoloop closure, Clip closure, Gallstone disease

INTRODUCTION

Laparoscopic cholecystectomy is one of the most frequently performed procedures in general surgery and is currently regarded as the gold standard treatment for symptomatic cholelithiasis, chronic cholecystitis, and selected cases of acute cholecystitis. The procedure offers several advantages over open cholecystectomy, including reduced postoperative pain, shorter hospital stays, earlier return to normal activities, and improved cosmetic outcomes.[1] Despite its safety and widespread acceptance, laparoscopic cholecystectomy is associated with specific biliary complications, among which postoperative bile leak remains clinically significant. Bile leakage may arise from injury to the biliary tree, accessory ducts, or the cystic duct stump. Cystic duct stump leakage is considered one of the most common and potentially preventable causes of postoperative bile leak, contributing to increased morbidity, prolonged hospitalization, additional interventions, and healthcare costs.[2,3] Secure closure of the cystic duct is therefore a critical step during laparoscopic cholecystectomy.

Metallic clips remain the most commonly used method because of their ease of application and operative convenience. However, concerns have been raised regarding clip slippage, displacement, and incomplete duct occlusion, particularly in patients with inflamed, edematous, or dilated cystic ducts. Alternative methods such as intracorporeal ligation, endoloop ligation, and energy-based sealing devices have been proposed to improve the security of cystic duct closure.[4]

Although several techniques for cystic duct occlusion are available, evidence regarding their comparative effectiveness in preventing postoperative bile leak remains limited.[5] The present study was undertaken to compare loop ligature closure and clip closure of the cystic duct during laparoscopic cholecystectomy and to evaluate their efficacy in preventing postoperative bile leakage.

METHODS

This prospective comparative study was conducted in the Department of General Surgery, Government Stanley Medical College Hospital, Chennai, between August 2023 and September 2025. After obtaining Institutional Ethics Committee approval and written informed consent, 100 adult patients with symptomatic cholelithiasis or acute calculous cholecystitis scheduled for elective laparoscopic cholecystectomy were enrolled.

Inclusion criteria

It includes age ≥18 years, both sexes, ultrasonography-confirmed gallstone disease, symptomatic cholelithiasis or acute calculous cholecystitis, willingness to provide informed consent.

Exclusion criteria

Refusal to participate, age <18 years, cholecystectomy performed for indications other than gallstone disease, patients unfit for general anesthesia were excluded.

Patients were allocated into two groups by alternate allocation. Group A (n=50) underwent cystic duct closure using a 2-0 polyglactin 910 loop ligature applied by extracorporeal knotting technique, while Group B (n=50) underwent cystic duct closure using non-absorbable metallic clips. All patients underwent standard four-port laparoscopic cholecystectomy with attainment of the critical view of safety before division of the cystic structures.

In Group A, the cystic artery was clipped and divided, following which two proximal and one distal 2-0 polyglactin 910 ligatures were placed on the cystic duct before transection. In Group B, the cystic duct and cystic artery were secured using two proximal and one distal metallic clip and divided between the clips. A subhepatic drain was placed in all patients. Three patients required conversion to open cholecystectomy (two in Group A and one in Group B) and were excluded from the final analysis, resulting in 48 patients in Group A and 49 patients in Group B.

The primary outcome measure was the occurrence of postoperative bile leak. Bile leak was defined as the presence of bile-stained drainage from the sub hepatic drain and/or radiological evidence of intra-abdominal bile collection attributable to leakage from the biliary system. Patients were monitored clinically and biochemically for evidence of bile leakage during hospitalization. Drain output was assessed daily and drains were removed when the output was less than 20 mL over 24 hours. All patients were discharged once clinically stable and followed up at 2 weeks, 1 month, and 3 months postoperatively to assess for complications.

Statistical analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics for Windows, Version 23.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize the study data. Categorical variables were expressed as frequencies and percentages, while continuous variables were presented as mean±standard deviation (SD).

Comparisons between the two study groups were performed using the independent samples t-test for continuous variables. Categorical variables were compared using the Chi-square test or Fisher's exact test, as appropriate. A p value of less than 0.05 was considered statistically significant.

RESULTS

The study population was evenly distributed between Group A (49.5%) and Group B (50.0%). Most patients were aged 31–50 years (65.0%), and females constituted 73.2% of the study cohort (Table 1). No significant differences were observed between the groups with respect to age distribution (χ^2=2.193, p=0.700), gender (χ^2=0.270, p=0.603), comorbidities (χ^2=3.655, p=0.455), previous cholecystitis (p=0.268), preoperative ERCP with or without stenting (χ^2=0.002, p=0.961), pancreatitis (p=0.436), indication for surgery (χ^2=0.185, p=0.667), operative findings (χ^2=0.380, p=0.537), or bile leakage (p=1.000) (Tables 2-6).

Comparative analysis of perioperative outcomes demonstrated no significant differences in preoperative total bilirubin levels (t=0.620, p=0.537), postoperative total bilirubin levels (t=1.299, p=0.197) (Table 7), or length of hospital stay (t=0.049, p=0.961) between the two groups (Table 8). Postoperative pain assessment using the visual analogue scale (VAS) at 2 weeks, 1 month, and 3 months revealed no statistically significant differences between the groups at any follow-up interval (Figure 1) (Table 9).

Table 1: Baseline demographic characteristics of the study participants (n=97).

Variables	Category	Frequency (n=97)	Percentage
Group	Group A	48	49.5
	Group B	49	50.5
Age distribution (in years)	Up to 30	12	12.4
	31–40	31	32.0
	41–50	32	33.0
	51–60	17	17.5
	Above 60	5	5.2
Gender	Female	71	73.2
	Male	26	26.8

Table 2: Comparison of baseline demographic characteristics between groups.

Variables	Category	Group A (n=48)	Group B (n=49)	Total (n=97)	χ^2 value	P value
Age (in years)	Up to 30	6 (12.5%)	6 (12.2%)	12 (12.4%)	2.193	0.700
	31–40	16 (33.3%)	15 (30.6%)	31 (32.0%)		
	41–50	18 (37.5%)	14 (28.6%)	32 (33.0%)		
	51–60	6 (12.5%)	11 (22.4%)	17 (17.5%)		
	Above 60	2 (4.2%)	3 (6.1%)	5 (5.2%)		
Gender	Female	34 (70.8%)	37 (75.5%)	71 (73.2%)	0.270	0.603
	Male	14 (29.2%)	12 (24.5%)	26 (26.8%)		

Table 3: Comparison of comorbidities between the groups.

Variables	Category	Group A (n=48)	Group B (n=49)	Total (n=97)	χ^2 value	P value
Comorbidities	CAD	3 (6.3%)	2 (4.1%)	5 (5.2%)	3.655	0.455
	Diabetes mellitus	9 (18.8%)	13 (26.5%)	22 (22.7%)		
	Hypertension	5 (10.4%)	1 (2.0%)	6 (6.2%)		
	Hypothyroidism	4 (8.3%)	4 (8.2%)	8 (8.2%)		
	No comorbidity	27 (56.3%)	29 (59.2%)	56 (57.7%)		

Table 4: Comparison of baseline clinical characteristics between the groups.

Variables	Category	Group A (n=48)	Group B (n=49)	Total (n=97)	χ^2/Fisher's test value	P value
Previous cholecystitis	Present	5 (10.4%)	2 (4.1%)	7 (7.2%)	1.453	0.268
	Absent	43 (89.6%)	47 (95.9%)	90 (92.8%)		
Preoperative ERCP±stenting	Present	9 (18.8%)	9 (18.4%)	18 (18.6%)	0.002	0.961
	Absent	39 (81.3%)	40 (81.6%)	79 (81.4%)		
Pancreatitis	Present	2 (4.2%)	5 (10.2%)	7 (7.2%)	1.320	0.436
	Absent	46 (95.8%)	44 (89.8%)	90 (92.8%)		

Table 5: Comparison of indication for surgery and operative findings between the groups.

Variable	Category	Group A (n=48)	Group B (n=49)	Total (n=97)	χ^2 value	P value
Indication for surgery	Acute cholecystitis	10 (20.8%)	12 (24.5%)	22 (22.7%)	0.185	0.667
	Symptomatic cholelithiasis	38 (79.2%)	37 (75.5%)	75 (77.3%)		
Operative findings	Inflamed gallbladder	12 (25.0%)	15 (30.6%)	27 (27.8%)	0.380	0.537
	Quiescent gallbladder	36 (75.0%)	34 (69.4%)	70 (72.2%)		

Table 6: Comparison of bile leakage between the groups.

Variable	Category	Group A (n=48)	Group B (n=49)	Total (n=97)	χ^2/Fisher's test value	P value
Bile leakage	No	47 (97.9%)	47 (95.9%)	94 (96.9%)	0.323	1.000
	Yes	1 (2.1%)	2 (4.1%)	3 (3.1%)		

Table 7: Comparison of preoperative and postoperative total bilirubin levels between the study groups.

Variable	Group	N	Mean	SD	t-value	P value
Preoperative total bilirubin	Group A	48	0.64	0.30	0.620	0.537
	Group B	49	0.68	0.39		
Postoperative total bilirubin	Group A	48	0.68	0.38	1.299	0.197
	Group B	49	0.84	0.74		

Table 8: Comparison of length of hospital stay in days between the groups.

Variable	Group	N	Mean	SD	t-value	P value
Length of hospital stay (days)	Group A	48	2.46	1.09	0.049	0.961
	Group B	49	2.47	1.14		

Table 9: Comparison of visual analogue scale scores between groups at 2 weeks, 1 month, and 3 months postoperatively.

Follow-up period	Group	N	Mean	SD	Z-value	P value
2 weeks	Group A	48	1.90	1.22	0.125	0.901
	Group B	49	1.80	1.00		
1 month	Group A	48	1.21	0.90	1.241	0.215
	Group B	49	0.98	0.83		
3 months	Group A	48	0.21	0.41	0.192	0.848
	Group B	49	0.22	0.42		

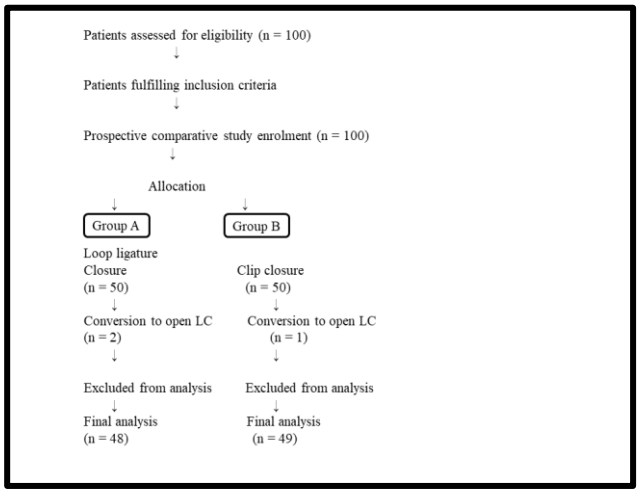

Figure 1: Patient selection and allocation into study groups.

DISCUSSION

The present prospective comparative study evaluated the effectiveness of loop closure versus clip closure of the cystic duct during laparoscopic cholecystectomy in 97 patients. Three patients who required conversion to open cholecystectomy were excluded from the final analysis. Postoperative bile leak occurred in three patients overall, with no statistically significant difference between the two groups. Similarly, postoperative bilirubin levels, duration of hospital stay, and postoperative pain scores were comparable between patients undergoing loop closure and clip closure.

These findings indicate that both techniques provide safe and effective cystic duct occlusion during laparoscopic cholecystectomy. Bile leak remains one of the most important complications following laparoscopic cholecystectomy because it is associated with prolonged hospitalization, additional interventions, and increased healthcare costs.[2,5] In the present study, bile leakage was uncommon and resolved with conservative management. The low incidence observed in both groups is consistent with previous reports demonstrating that secure cystic duct closure is associated with excellent postoperative outcomes irrespective of the closure method employed. The findings are comparable with those reported by Donkervoort et al who evaluated cystic duct closure using a polydioxanone loop and observed very low rates of postoperative bile leakage.[6] Although their study suggested a potential advantage of loop closure in patients at increased risk of bile leakage, the present study demonstrated comparable outcomes between loop closure and clip closure in a general laparoscopic

cholecystectomy population. Several studies have investigated alternative methods of cystic duct occlusion, including ligatures, polymer clips, absorbable clips, and energy-based devices. A recent review of cystic duct closure techniques reported that absorbable and ligature-based methods may reduce postoperative bile leakage while maintaining safety comparable to conventional clips.[5] However, the overall incidence of bile leak remains low with both approaches, and current evidence does not conclusively establish the superiority of any single closure technique.

The findings of the present study are also consistent with systematic reviews evaluating clip-based and clipless techniques. The systematic review by Gurusamy et al found no clear superiority of one method over another because of limited evidence regarding postoperative complications and long-term outcomes.[5] Although ligature-based techniques may require slightly longer operative times, operative duration was comparable between the two groups in the present study, suggesting that loop closure can be performed efficiently when the technique is familiar to the surgeon.

Studies evaluating clipless laparoscopic cholecystectomy using sutures or energy devices have similarly demonstrated acceptable safety profiles. Wills and Crawford reported bile leak rates comparable to those observed with conventional clip application.[7] Gelmini et al reported that laparoscopic cholecystectomy performed using the Harmonic scalpel was a safe and feasible clipless technique, with acceptable operative outcomes and low incidence of postoperative biliary complications.[8] Collectively, these findings support the concept that secure cystic duct occlusion, rather than the specific method employed, is the key determinant of successful surgical outcomes.

Loop closure offers several practical advantages. The ligature material is inexpensive, widely available, and avoids the placement of permanent metallic implants. It may be particularly useful in patients with a wide cystic duct, where clip security can be a concern. Rare complications associated with clips, including clip migration and hypersensitivity reactions, have also been described in the literature, providing a rationale for considering non-metallic alternatives in selected cases.[9] Nevertheless, these complications are uncommon, and clip closure remains a safe and widely accepted technique. Although loop closure may offer economic advantages, the present study was not designed to perform a formal cost-effectiveness analysis, and therefore definitive conclusions regarding cost benefit cannot be drawn. The safety of laparoscopic cholecystectomy depends not only on the method of cystic duct closure but also on meticulous surgical technique. Accurate identification of biliary anatomy, recognition of anatomical variations, and strict adherence to the critical view of safety remain the most important factors in preventing biliary complications.[2,10] Contemporary evidence continues to emphasize that these principles have a greater influence on patient outcomes than the choice of closure device alone. In the present study, both closure techniques were associated with low complication rates and satisfactory postoperative recovery. No significant differences were observed in bile leak rates, postoperative bilirubin levels, hospital stay, or postoperative pain scores. These findings suggest that loop closure is a feasible and safe alternative to conventional clip closure without compromising patient outcomes.

The present study has certain limitations. First, it was conducted at a single centre with a relatively small sample size, which may have limited the ability to detect small differences in bile leak rates between the groups. Second, laparoscopic cholecystectomy was performed by multiple surgeons with varying levels of experience, which may have influenced operative outcomes. Third, the low incidence of postoperative bile leak restricted the statistical power for evaluating this complication as a primary outcome. Larger multicentre studies with longer follow-up periods are required to validate these findings.

Despite these limitations, the study provides prospective comparative data regarding two commonly used methods of cystic duct closure. The findings suggest that loop closure is a safe and effective alternative to clip closure during laparoscopic cholecystectomy and may be particularly useful in settings where cost considerations are important.

CONCLUSION

Loop closure and clip closure of the cystic duct during laparoscopic cholecystectomy demonstrated comparable postoperative outcomes, including bile leak rates, postoperative pain, bilirubin levels, and duration of hospital stay. No statistically significant advantage of either technique was identified. Loop closure represents a safe, practical, and economical alternative to conventional clip closure. Further large-scale multicentre studies are warranted to confirm these findings and evaluate long-term outcomes.

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