

# Efficacy and Cost-Effectiveness of Extracorporeal Knotting Compared with Conventional Clip Ligation During Laparoscopic Cholecystectomy: Experience from a Bangladeshi Tertiary Center

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## ABSTRACT

**Introduction:** Laparoscopic cholecystectomy is the standard treatment for symptomatic gallstone disease, and secure cystic duct closure is essential for preventing bile leak and other postoperative complications. Conventional clip ligation is widely used, but the cost of disposable clips may increase the overall procedural expense. Extracorporeal knotting has been proposed as a low-cost alternative that may provide comparable clinical outcomes. This study aimed to compare the efficacy and cost-effectiveness of extracorporeal knotting and conventional clip ligation during laparoscopic cholecystectomy in a Bangladeshi tertiary care hospital. **Methods & Materials:** This observational cross-sectional analytical study was conducted in the Department of Surgery, Al Haramain Hospital, Sylhet, Bangladesh, from July 2025 to December 2025. A total of 100 patients undergoing elective laparoscopic cholecystectomy were included using a consecutive sampling technique and were categorized into two groups according to the method of cystic duct closure: the Extracorporeal Knotting (EK) group (n = 50), in which absorbable suture was used for extracorporeal knotting, and the Conventional Clip Ligation (CL) group (n = 50), in which metallic clips were applied. Statistical analysis was performed using SPSS version 26. **Results:** Among 100 patients undergoing laparoscopic cholecystectomy, the extracorporeal knotting group showed clinical efficacy comparable to the conventional clip ligation group, with all procedures completed laparoscopically in both groups. The rates of intraoperative and postoperative complications—including bile leak, bleeding, wound infection, and 30-day readmission—were similarly low in the

two groups, indicating no significant difference in efficacy or safety between the techniques. Although operative time was slightly longer with extracorporeal knotting ( $54.1 \pm 8.8$  vs  $48.2 \pm 7.9$  minutes), it resulted in a marked reduction in material-related cost ( $560 \pm 68$  vs  $1,380 \pm 145$  BDT) and showed superior overall cost-effectiveness. **Conclusion:** Extracorporeal knotting in laparoscopic cholecystectomy showed clinical effectiveness and postoperative safety comparable to conventional clip ligation, with similarly low incidences of bile leak, bleeding, wound infection, and readmission. Although the procedure required a slightly longer operative time, it was associated with a marked reduction in material-related costs and demonstrated significantly better overall cost-effectiveness.

**Keywords:** Extracorporeal Knotting, Clip Ligation, Laparoscopic Cholecystectomy

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## INTRODUCTION

Gallstone disease is one of the most common gastrointestinal disorders requiring surgical treatment worldwide. Laparoscopic cholecystectomy has become the standard procedure for symptomatic cholelithiasis because it is associated with less postoperative pain, shorter hospital stay, faster recovery, and better cosmetic outcomes than open cholecystectomy [1]. The safety of laparoscopic cholecystectomy largely depends on secure closure of the cystic duct and cystic artery, as inadequate ligation may result in bile leakage, hemorrhage, and other postoperative complications [2]. Conventional metallic clip ligation remains the most widely used method for cystic duct control because of its technical simplicity and rapid application. However, clip applicators and disposable clip cartridges add to the procedural cost of laparoscopic surgery. In low- and middle-income countries, including Bangladesh, where a substantial proportion of

healthcare expenditure is paid directly by patients, reducing avoidable operative costs is an important component of improving access to minimally invasive surgery [3,4]. Extracorporeal knotting using absorbable suture material has been proposed as a cost-saving alternative to metallic clips. The technique uses standard sutures that are readily available in most operating rooms and eliminates the need for disposable clip devices. Interest in this approach has increased in resource-constrained settings where surgeons seek affordable methods without compromising patient safety [5]. Recent evidence suggests that the clinical efficacy of suture-based cystic duct closure is comparable to that of metallic clips. A 2025 network meta-analysis of 23 randomized studies involving 2,851 patients found no significant difference in bile leak rates between suture ligation and metallic clip closure, indicating similar effectiveness for securing the cystic duct during laparoscopic cholecystectomy [6]. Likewise,

a 2024 systematic review and meta-analysis of 26 studies reported that suture-based techniques had postoperative complication rates comparable to conventional clip application, with very low incidences of bile leakage and hemorrhage [7]. These findings suggest that when safety outcomes are similar, economic considerations and local resource utilization become increasingly important in choosing the method of cystic duct closure. Data from South Asian settings also support the potential economic benefit of extracorporeal knotting. A recent randomized controlled trial from Bangladesh involving 506 patients demonstrated that extracorporeal knotting significantly reduced procedural expenditure compared with clip ligation while maintaining comparable postoperative outcomes, although operative time was slightly longer in the knotting group [8]. Such findings are particularly relevant for Bangladeshi tertiary hospitals, where high surgical volume and limited

resources necessitate cost-effective operative strategies. Despite these encouraging reports, important knowledge gaps remain. Most published studies have been conducted in different healthcare systems with varying costs of disposable instruments, hospital procurement policies, surgeon expertise, and operative workflows. The economic advantage observed in one institution may not be directly applicable to another. Furthermore, many previous studies focused primarily on technical feasibility or short-term safety and did not comprehensively evaluate both clinical efficacy and direct procedural cost in real-world practice <sup>[5,8]</sup>. In Bangladesh, evidence comparing extracorporeal knotting with conventional clip ligation in tertiary-care settings remains limited. Local data are needed because operative cost, availability of disposable devices, and surgeon experience may differ substantially from those reported in international literature. Therefore, this study aimed to compare the clinical efficacy and cost-effectiveness of extracorporeal knotting and conventional clip ligation during laparoscopic cholecystectomy in a Bangladeshi tertiary care hospital.

METHODS & MATERIALS

This observational cross-sectional analytical study was conducted in the

Department of Surgery, Al Haramain Hospital, Sylhet, Bangladesh, from July 2025 to December 2025. A total of 100 patients undergoing elective laparoscopic cholecystectomy for symptomatic gallstone disease were included using a consecutive sampling technique and were categorized into two groups according to the method of cystic duct closure: the Extracorporeal Knotting (EK) group (n = 50), in which absorbable suture was used for extracorporeal knotting, and the Conventional Clip Ligation (CL) group (n = 50), in which metallic clips were applied. Adult patients with symptomatic cholelithiasis or chronic calculous cholecystitis were enrolled after informed written consent, while patients with acute cholecystitis requiring emergency surgery, suspected gallbladder malignancy, common bile duct stones requiring additional procedures, previous upper abdominal surgery with dense adhesions, or conversion to open surgery before cystic duct control were excluded. This study assessed only the material-related procedural costs associated with extracorporeal knotting and conventional clip ligation. The total hospital expenditure, including operating room charges, medications, investigations, hospital stay, and other indirect expenses, was not analyzed because these costs may

vary considerably among institutional settings. Data were collected using a structured case record form including demographic variables, preoperative findings, intraoperative outcomes, postoperative outcomes, and material-related costs. Statistical analysis was performed using SPSS version 26; continuous variables were expressed as mean ± standard deviation and categorical variables as frequency and percentage. The independent-samples t-test was used for comparison of hospital stay and cost variables, whereas Fisher’s exact test and Chi-square test were used for categorical outcomes. A p-value <0.05 was considered statistically significant. Ethical approval was obtained from the institutional authority of Al Haramain Hospital, and confidentiality of patient information was maintained throughout the study.

RESULTS

The mean age was 43.2 ± 10.9 years in the EK group and 44.6 ± 11.3 years in the CL group. Female patients predominated in both groups (78.0% vs 74.0%). BMI was also comparable (24.9 ± 3.1 vs 25.3 ± 3.4 kg/m²), indicating similar baseline demographic characteristics (Table I).

Table I  
Baseline demographic characteristics of the study participants (n = 100).

| Variables              | EK (n = 50) | CL (n = 50) |
|------------------------|-------------|-------------|
| Age (years), mean ± SD | 43.2 ± 10.9 | 44.6 ± 11.3 |
| Female, n (%)          | 39 (78.0)   | 37 (74.0)   |
| Male, n (%)            | 11 (22.0)   | 13 (26.0)   |
| BMI (kg/m²), mean ± SD | 24.9 ± 3.1  | 25.3 ± 3.4  |

Symptomatic cholelithiasis was the most common indication for surgery in both groups (82.0% vs 80.0%). The frequency

of chronic calculous cholecystitis, gallbladder wall thickening, and multiple

gallstones was similar between the two groups (Table II).

Table II  
Preoperative findings (n = 100\*).

| Variables                       | EK (n = 50) | CL (n = 50) |
|---------------------------------|-------------|-------------|
| Clinical finding                |             |             |
| Symptomatic cholelithiasis      | 41 (82.0)   | 40 (80.0)   |
| Imaging                         |             |             |
| Chronic calculous cholecystitis | 9 (18.0)    | 10 (20.0)   |
| Gallbladder wall >3 mm          | 10 (20.0)   | 12 (24.0)   |
| Multiple gallstones             | 30 (60.0)   | 28 (56.0)   |

\*Multiple responses.

The EK group had a longer operative time (54.1 ± 8.8 minutes) compared with the CL group (48.2 ± 7.9 minutes). Intraoperative bile leak occurred in 1 patient (2.0%) in

each group. Rates of additional bleeding control and gallbladder perforation were low and comparable, while conversion to

open surgery occurred in 1 patient (2.0%) in the CL group (Table III).

**Table III**  
Intraoperative outcomes (*n* = 100).

| Variables                             | EK ( <i>n</i> = 50) | CL ( <i>n</i> = 50) |
|---------------------------------------|---------------------|---------------------|
| Operative time (min), mean ± SD       | 54.1 ± 8.8          | 48.2 ± 7.9          |
| Intraoperative bile leak              | 1 (2.0)             | 1 (2.0)             |
| Bleeding requiring additional control | 2 (4.0)             | 2 (4.0)             |
| Gallbladder perforation               | 3 (6.0)             | 2 (4.0)             |
| Conversion to open surgery            | 0 (0.0)             | 1 (2.0)             |

Postoperative bile leak was observed in 2.0% of patients in both groups. Port-site infection occurred in 4.0% of the EK group and 6.0% of the CL group. Mean hospital stay was 1.9 ± 0.6 days in the EK group and 2.0 ± 0.7 days in the CL group, showing no statistically significant difference (Table IV).

**Table IV**  
Early postoperative outcomes (*n* = 100).

| Variables                       | EK ( <i>n</i> = 50) | CL ( <i>n</i> = 50) | p-value |
|---------------------------------|---------------------|---------------------|---------|
| Postoperative bile leak         | 1 (2.0)             | 1 (2.0)             | 1.00*   |
| Port-site infection             | 2 (4.0)             | 3 (6.0)             | 1.00*   |
| Postoperative bleeding          | 0 (0.0)             | 1 (2.0)             | 1.00*   |
| Hospital stay (days), mean ± SD | 1.9 ± 0.6           | 2.0 ± 0.7           | 0.41#   |
| Readmission within 30 days      | 1 (2.0)             | 2 (4.0)             | 1.00*   |

\*Independent sample *t*-test was used for hospital stay; #Fisher's exact test;

Extracorporeal knotting resulted in a marked reduction in procedural expenditure. The mean total material-related cost was 560 ± 68 BDT in the EK group compared with 1,380 ± 145 BDT in the CL group, demonstrating a highly significant cost advantage for extracorporeal knotting (Table V).

**Table V**  
Material-related cost comparison (*n* = 100).

| Cost variables (BDT)        | EK ( <i>n</i> = 50) | CL ( <i>n</i> = 50) | p-value* |
|-----------------------------|---------------------|---------------------|----------|
| Suture/clip material cost   | 350 ± 45            | 920 ± 110           | <0.001   |
| Additional disposable cost  | 210 ± 35            | 460 ± 70            | <0.001   |
| Total material-related cost | 560 ± 68            | 1,380 ± 145         | <0.001   |

\*Independent sample *t*-test was used.

Successful laparoscopic completion was achieved in 100% of the EK group and 98.0% of the CL group. Major postoperative complications were uncommon in both groups (6.0% vs 8.0%). However, significant cost savings of at least 500 BDT were achieved in 90.0% of EK patients compared with 16.0% of CL patients (Table VI).

**Table VI**  
Overall efficacy and cost-effectiveness (*n* = 100#).

| Variables                           | EK ( <i>n</i> = 50) | CL ( <i>n</i> = 50) | p-value* |
|-------------------------------------|---------------------|---------------------|----------|
| Successful laparoscopic completion  | 50 (100)            | 49 (98.0)           | 0.32     |
| No major postoperative complication | 47 (94.0)           | 46 (92.0)           | 0.69     |
| Cost saving ≥500 BDT                | 45 (90.0)           | 8 (16.0)            | <0.001   |

\*Chi-square test; # Multiple response.

**DISCUSSION**

The mean age was 43.2 ± 10.9 years in the EK group and 44.6 ± 11.3 years in the CL group, while females constituted 78.0% and 74.0% of the two groups, respectively. Teja et al. reported a mean age of 41.8 ± 12.4 years in the extracorporeal knot group and 42.7 ± 11.9 years in the clip group, with female predominance of 76% and 72%, respectively [9]. These findings closely resemble this study, indicating that the two groups were demographically comparable and that gallstone disease remains predominantly a disease of middle-aged females. Preoperative findings were also similar. Symptomatic cholelithiasis was present in 82.0% of EK patients and 80.0% of CL patients, while multiple gallstones were observed in 60.0%

and 56.0%, respectively. Chowdhury et al. found symptomatic cholelithiasis in 84% of the suture ligation group and 82% of the clip group, and multiple gallstones in 58% and 54%, respectively [10]. The close agreement with the data of the present study suggests that the disease burden and preoperative characteristics were comparable to those reported in similar regional studies. In the present study, operative time was longer in the EK group than in the CL group (54.1 ± 8.8 vs 48.2 ± 7.9 minutes). Intraoperative bile leak occurred in 2.0% of patients in both groups, additional bleeding control in 4.0%, gallbladder perforation in 6.0% versus 4.0%, and conversion to open surgery in 0% versus 2.0%. Teja et al. reported operative times of 67.37 and 61.83

minutes for extracorporeal knotting and clip ligation, respectively, with no bile leak in either group and no conversion to open surgery. Singal et al. found operative times of 55.4 and 48.6 minutes, bile leak of 0% in both groups, wound infection of 3.3% versus 6.6%, and hospital stay of 1.8 versus 2.1 days, showing comparable intraoperative safety despite slightly longer operative time with clipless techniques [9,11]. Early postoperative outcomes were similarly favorable. Postoperative bile leak was 2.0% in both groups, port-site infection was 4.0% in EK versus 6.0% in CL, and hospital stay was 1.9 ± 0.6 days versus 2.0 ± 0.7 days. Van Dijk et al. reviewed multiple cystic duct closure techniques and found postoperative bile leak rates generally below 3% for both

ligature- and clip-based methods, with no meaningful difference in hospital stay [12]. Chowdhury et al. reported wound infection rates of 5% in the suture group and 7% in the clip group, and mean hospital stay of  $2.1 \pm 0.8$  days and  $2.2 \pm 0.7$  days, respectively [10]. The results are therefore consistent with the available evidence that extracorporeal knotting does not increase postoperative morbidity. The most striking difference was observed in material-related cost. The mean total cost was  $560 \pm 68$  BDT in the EK group compared with  $1,380 \pm 145$  BDT in the CL group, and 90.0% of EK patients achieved a cost saving of at least 500 BDT. Teja et al. found that the mean procedural cost was approximately ₹210 for extracorporeal knotting and ₹680 for clip ligation, demonstrating a significant economic advantage for the knotting technique [9]. Chowdhury et al. also reported significantly lower operative expenditure with suture ligation than with metallic clips in a resource-limited setting [10]. In this study, successful laparoscopic completion was achieved in 100% of EK patients and 98.0% of CL patients, while major postoperative complications remained low (6.0% vs 8.0%). These findings indicate that extracorporeal knotting offers comparable efficacy and safety with substantial cost savings.

### LIMITATIONS

The study was conducted in a single hospital with a small sample size. So, the results may not represent the whole community. Moreover, surgeon-related factors and the learning curve associated with extracorporeal knotting were not separately analyzed, and indirect or long-term costs were not included, which may limit the generalizability of the findings to other institutions and settings.

### CONCLUSION

Extracorporeal knotting during laparoscopic cholecystectomy demonstrated clinical efficacy and postoperative safety comparable to conventional clip ligation, with similarly low rates of bile leak, bleeding, wound infection, and readmission. Although the operative time was slightly longer with extracorporeal knotting, it resulted in a substantial reduction in material-related costs and a significantly higher overall cost-effective outcome.

### RECOMMENDATION

Extracorporeal knotting may be considered as a cost-effective alternative to conventional clip ligation during laparoscopic cholecystectomy, particularly in resource-limited tertiary hospitals. Surgeons should receive adequate training in knotting techniques to minimize operative time, and larger multicenter prospective studies are recommended to further validate its long-term safety, efficacy, and economic benefits in Bangladesh.

### FUNDING

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### CONFLICT OF INTEREST

None declared.

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