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Original Research Article

GEA knot for cystic duct and artery ligation in laparoscopic cholecystectomy

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ABSTRACT

Background: The GEA knot has emerged as a potential alternative to conventional clips or staplers for cystic duct and artery ligation during laparoscopic cholecystectomy. However, its safety and efficiency remain under-evaluated in clinical practice.
Methods: This retrospective study included 178 patients who underwent laparoscopic cholecystectomy with GEA knot ligation. Demographic data, operative time, intraoperative and postoperative complications, and hospital stay were analyzed. A subgroup analysis compared the first 50 versus last 50 procedures to evaluate learning curve. A multivariate linear regression model identified predictors of operative time.
Results: Mean age was 44.2±11.7 years; 63.5% were female. Mean operative time was 48.6±12.4 minutes and mean hospital stay was 1.2±0.6 days. No major complications occurred. Intraoperative bleeding (1.1%) and conversion to open surgery (0.6%) were rare. Only one case of superficial wound infection was recorded (0.6%). Operative time decreased significantly from the first 50 cases (54.1±10.6 min) to the last 50 cases (45.3±9.2 min; $p=0.001$). Regression analysis showed that male sex ($\beta = +2.5$, $p=0.04$) and case order ($\beta = -0.31$ per case, $p<0.001$) were significant predictors of operative time (adjusted $R^2 = 0.41$).
Conclusions: The GEA knot is a safe and effective method for cystic duct and artery ligation. It demonstrates a short learning curve and excellent safety profile, with potential advantages in cost and resource-limited settings.

Keywords: Cystic duct, GEA knot, Laparoscopic cholecystectomy, Minimally invasive surgery, Suture techniques

INTRODUCTION

Laparoscopic cholecystectomy has become the gold standard for the surgical management of symptomatic gallstone disease, offering significant advantages in terms of postoperative recovery and patient satisfaction.[1] Critical to the safety of this procedure is secure ligation of the cystic duct and artery, which traditionally involves the use of metallic clips or endoloops.[2] However, in low-resource settings, the cost and availability of these materials may limit their use.

Alternative ligation techniques that are safe, effective, and reproducible are essential in these environments. The extracorporeal sliding knot, particularly the GEA knot, has emerged as a promising method for ligating tubular structures during laparoscopy.[3,4] This knot is manually tied outside the body and then advanced intracorporeally using standard laparoscopic instruments, offering a low-cost, adaptable solution without the need for proprietary devices.

Despite anecdotal support for its use, few studies have systematically evaluated the clinical outcomes of GEA knot application in cystic duct and artery ligation during laparoscopic cholecystectomy. In particular, data are lacking regarding its safety profile, intraoperative handling, and postoperative complications when used as

the sole ligation method. This study aimed to evaluate the effectiveness and safety of the GEA knot in the ligation of the cystic duct and artery during laparoscopic cholecystectomy, within setting in a developing country. The findings may offer evidence to support the broader use of this technique, particularly in institutions facing economic and logistical constraints.

METHODS

Study design

A retrospective observational study was conducted on a cohort of patients who underwent laparoscopic cholecystectomy with cystic duct and artery ligation using the GEA knot technique at SURGCLINIC Hospital between January 2021 and December 2024.

Inclusion criteria

Patients aged 18 years or older. Elective laparoscopic cholecystectomy performed for cholelithiasis or chronic calculous cholecystitis. Exclusive use of the GEA knot for cystic duct and artery ligation.

Exclusion criteria

Cases involving open cholecystectomy from the outset. Use of clips or any alternative ligation techniques. Acute cholecystitis grade II or III as defined by the Tokyo guidelines.

Surgical technique

A standard four-port laparoscopic approach was used in all cases. The cystic duct and artery were dissected, clearly identified, and ligated using extracorporeal GEA knots tied with Polypropylene 1 (PROLENE), depending on suture availability (Figure 1, and Figure 2). The gallbladder was then dissected from the liver bed and extracted using an endoscopic retrieval bag.

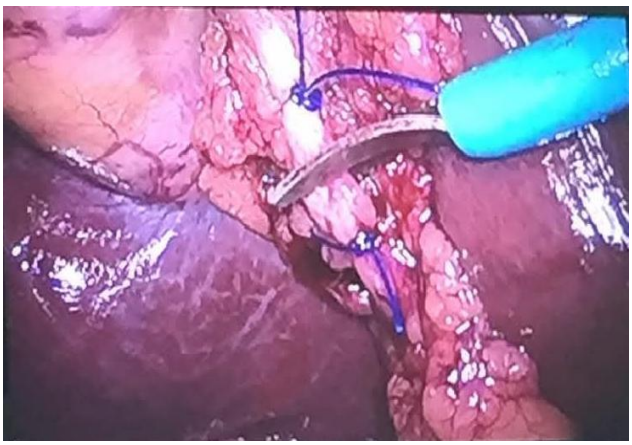

Figure 1: Application of the GEA knot for cystic duct ligation.

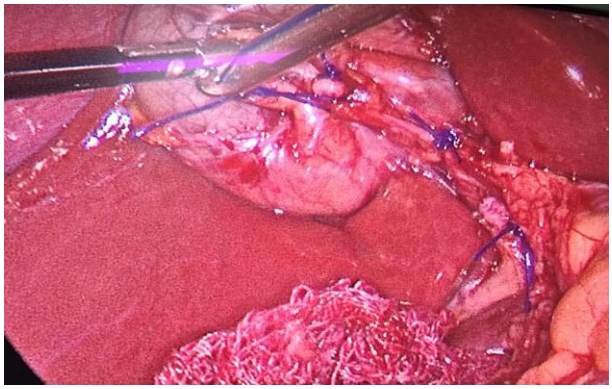

Figure 2: Application of the GEA knot for cystic duct and artery ligation.

Variables analysis

The following variables were collected and analysed demographic data (age, sex), operative time (minutes), intraoperative complications (bleeding, bile duct injury, conversion to open surgery), postoperative complications (bile leak, surgical site infection, intra-abdominal collection), and length of hospital stay (days).

Statistical analysis

Categorical variables (sex, intraoperative and postoperative complications) were described as frequencies and percentages. Continuous variables (age, operative time, hospital stay) were expressed as mean ± standard deviation (SD) or median (IQR), according to their distribution, assessed by the Shapiro–Wilk test. Comparisons between the first and last 50 cases were performed using Student's *t*-test for normally distributed variables. Multiple linear regression was used to identify predictors of operative time, including age, sex, and case order (cumulative sequence). Model fit was evaluated using adjusted R^2 and ANOVA. A p value <0.05 was considered statistically significant. All analyses were performed using SPSS® v26 (IBM Corp).

RESULTS

A total of 178 patients underwent laparoscopic cholecystectomy with cystic duct and artery ligation using the GEA knot. Data were obtained from an institutional database, with no missing cases.

Demographic and clinical data

The mean age was 44.2±11.7 years (range: 18-72), with a predominance of female patients (63.5%), consistent with the known epidemiology of cholelithiasis.

The mean operative time was 48.6±12.4 minutes (range: 30-80), and the mean length of hospital stay was 1.2±0.6 days (range: 1-3). No patients required intensive care or blood transfusion in the postoperative period (Table 1).

Table 1: Demographic and perioperative characteristics of the study population.

Variable	Mean ± SD	Range
Age (years)	44.2±11.7	18-72
Operative time (minutes)	48.6±12.4	30-80
Hospital stay (days)	1.2±0.6	1-3

Intraoperative and postoperative complications

Complication rates were very low, with no bile duct injuries reported. There were two cases of minor intraoperative bleeding (1.1%), both managed conservatively, and one conversion to open surgery (0.6%) due to dense adhesions in Calot's triangle. Only one case of superficial surgical site infection (0.6%) was recorded in the postoperative period. No bile leaks, intra-abdominal collections, or 30-day readmissions occurred (Table 2).

Table 2: Intraoperative and postoperative complications.

Complication	Number	Percent
Bile duct injury	0	0.0
Minor intraoperative bleeding	2	1.1
Conversion to open surgery	1	0.6
Postoperative bile leak	0	0.0
Surgical site infection	1	0.6
Readmission within 30 days	0	0.0

Learning curve analysis (first 50 vs last 50 cases)

A subgroup comparison was performed between the first 50 procedures and the last 50 to evaluate the impact of surgeon experience on efficiency. A significant reduction in operative time was observed with case progression (Table 3).

Table 3: Operative time comparison between early and late cases.

Group	Operative Time (min)	P value
First 50 cases	54.1±10.6	0.001**
Last 50 cases	45.3±9.2	

**Significant

The analysis revealed a statistically significant difference ($p<0.01$), suggesting a short and effective learning curve for the GEA knot technique.

Predictors of operative time

A multiple linear regression model was constructed to identify independent predictors of operative time. The variables included were age, sex, and sequential case number (as a proxy for experience).

Male sex was associated with a slight but significant increase in operative time ($\beta = +2.5$ minutes; $p=0.04$), while increased experience (case sequence) was linked to a significant reduction ($\beta = -0.31$ per case; $p<0.001$). The model had an adjusted R^2 of 0.41 and was globally significant (ANOVA $p<0.001$).

Table 4: Multivariate linear regression model for operative time predictors.

Variable	β coefficient	Standard error	P value
Age (years)	0.13	0.08	0.09
Sex (1 = Male)	+2.5	1.2	0.04*
Case order	-0.31	0.07	<0.001**

*globally significant; **significant

DISCUSSION

In this retrospective cohort of 178 patients undergoing laparoscopic cholecystectomy with cystic duct and artery ligation using the GEA knot, we observed minimal complication rates and a significant reduction in operative time as surgeon experience increased. These findings support the safety and efficiency of the GEA knot as a feasible alternative to conventional ligation methods.

Safety and complication rates

The absence of bile duct injuries and bile leaks in our cohort compares favorably with large-scale pooled data from over 500,000 cases, which estimated major bile duct injury at about 0.28%, bile leak at 0.46%, and overall morbidity between 1.6-5.3%.[1,3] These rates are consistent with systematic reviews and audits of laparoscopic cholecystectomy safety.[3,4] Our results suggest that the GEA knot may achieve comparable outcomes while avoiding device-related costs and risks.

Operative time and learning curve

With a mean operative time of 48.6 minutes and a significant reduction from 54.1 to 45.3 minutes between early and late cases ($p=0.001$), our findings align with classical learning curve data. In a series of 416 cases, mean operative times decreased from 97 to 74 minutes after about 35 cases.[5] Larger institutional reports also demonstrate stabilization of operation time after 50–60 cases.[6,7] Our multivariate model confirmed case order as an independent predictor of reduced operative time ($\beta = -0.31$; $p<0.001$), reflecting efficiency gains typical of experience.

Comparison of ligation techniques

Systematic reviews comparing metal clips, polymer clips, suture ligation, and energy-based methods indicate that locking polymer clips and sutures may be marginally safer than metal clips regarding bile leak risk.[2,8] Our

technique, involving manual knotting (GEA), appears to match this level of safety without reliance on proprietary consumables. Additionally, ultrasonic (energy) methods have shown reductions in operative time and conversion rates compared to clips in randomized trials.[1,9]

Practical implications

The GEA knot's low complication profile, efficient learning curve, and elimination of disposables make it particularly valuable in resource-limited settings. It may be especially advantageous in cases with dilated cystic ducts where clip security is suboptimal.[8]

This study has several limitations. Firstly, single-centre retrospective design, absence of a direct comparator group, and potential unmeasured confounders such as BMI, inflammation grade, duct anatomy, or surgical trainee involvement. The regression model's adjusted R^2 of 0.41 reflects moderate predictive power. Furthermore, long-term outcomes and late biliary complications were not assessed. Prospective, randomized multicentre trials are warranted to validate these findings.

CONCLUSION

Ligation of the cystic duct and artery using the GEA knot during laparoscopic cholecystectomy appears safe, efficient, and reproducible, with minimal complications and demonstrable reductions in operative time. Its low-cost design and rapid learning curve make it an attractive alternative to clip-based methods. Larger prospective studies are needed to establish its comparative efficacy and generalizability.

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Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee of SURGCLINIC Hospital, Pelileo, Ecuador

REFERENCES

1. Strasberg SM, Hertl M, Soper NJ. An analysis of the problem of biliary injury during laparoscopic cholecystectomy. J Am Coll Surg. 1995;180(1):101-25.
2. Sharma S, Behari A, Shukla R, Dasari M, Kapoor VK. Bile duct injury during laparoscopic cholecystectomy: An Indian e survey. Ann Hepatobiliary Pancreat Surg. 2020;24(4):469-76.
3. Gurusamy K, Samraj K, Gluud C, Wilson E, Davidson BR. Meta analysis of randomized controlled trials on the safety and effectiveness of early versus delayed laparoscopic cholecystectomy for acute cholecystitis. Br J Surg. 2010;97(2):141-50.
4. Gupta A, Agrawal S, Sharma N, Parth N. Extra hepatic bile duct injury after laparoscopic cholecystectomy: a retrospective study. Int Surg J. 2020;7(8):2517-22.
5. Komatsu M, Yokoyama N, Katada T, Sato D, Otani T, Harada R, et al. Learning curve for the surgical time of laparoscopic cholecystectomy performed by surgical trainees using the three port method: how many cases are needed for stabilization? Surg Endosc. 2023;37(2):1252-61.
6. Peterli R, Herzog U, Schuppisser JP, Ackermann C, Tondelli P. The learning curve of laparoscopic cholecystectomy and changes in indications: one institution's experience with 2,650 cholecystectomies. J Laparoendosc Adv Surg Tech A. 2000;10(1):13-9.
7. Deziel DJ, Millikan KW, Staren ED, Doolas A, Economou SG. The impact of laparoscopic cholecystectomy on the operative experience of surgical residents. Surg Endosc. 1993;7(1):17-21.
8. van Dijk AH, van Roessel S, de Reuver PR, Boerma D, Boermeester MA, Donkervoort SC. Systematic review of cystic duct closure techniques in relation to prevention of bile duct leakage after laparoscopic cholecystectomy. World J Gastrointest Surg. 2018;10(6):57-69.
9. Arkle T, Lam S, Toogood G, Kumar B. How should we secure the cystic duct during laparoscopic cholecystectomy? A UK wide survey of clinical practice and systematic review of the literature with meta-analysis. Ann R Coll Surg Engl. 2022;104(9):650-4.
10. Booij KA, de Reuver PR, Yap K, van Dieren S, van Delden OM, Rauws EA, et al. Morbidity and mortality after minor bile duct injury following laparoscopic cholecystectomy. Endosc. 2015;47(1):40-6.
11. Richardson MC, Bell G, Fullarton GM; West of Scotland Laparoscopic Cholecystectomy Audit Group. Incidence and nature of bile duct injuries following laparoscopic cholecystectomy: an audit of 5,913 cases. Br J Surg. 1996;83(10):1356-60.
12. Törnqvist B, Waage A, Zheng Z, Ye W, Nilsson M. Severity of acute cholecystitis and risk of iatrogenic bile duct injury during cholecystectomy: A population based case control study. World J Surg. 2016;40(5):1060-7.
13. Sgaramella Sgaramella LI, Gurrado A, Pasculli A, de Angelis N, Memeo R, Prete FP, et al. SYoN Italian Collaborative Group. The critical view of safety during laparoscopic cholecystectomy: Strasberg yes or no? An Italian multicentre study. Surg Endosc. 2021;35(7):3698-3708.
14. Vithayathil M, Yong C, Dawas K. Clinical outcomes of early and delayed cholecystectomy for acute gallstone-related disease. Turk J Surg. 2025;41(1):19-23.
15. Ferguson CM, Rattner DW, Warshaw AL. Bile duct injury in laparoscopic cholecystectomy. Surg Laparosc Endosc. 1992;2(1):1-7.

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