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Comparative Study of Methods of Laparoscopic Appendicular Stump Ligation

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ABSTRACT
Laparoscopic appendectomy is a common surgical procedure, with various techniques for appendicular stump ligation. This study compares the efficacy, operative time, cost and postoperative outcomes of three different stump ligation techniques conventional suturing, endoloop and GIA stapler. A total of 50 patients diagnosed with acute appendicitis at a tertiary care center were included in this prospective study. They underwent laparoscopic appendectomy using one of the three techniques. Data on operative time, cost and postoperative outcomes were collected and analyzed. The average operative time was shortest for the stapler group (88.3±13.3 min), followed by the endoloop (92.5±12.9 min) and conventional suturing groups (98.6±11.8 min) with a p-value of 0.119. The cost analysis showed the highest expenditure for the stapler group (6000 currency units) compared to the endoloop (1500 currency units) and conventional suturing groups (620±73 currency units), p<0.0001. Postoperative outcomes, including hospital stay and pain (VAS scores), did not significantly differ among the groups. While the stapler technique is less time-consuming, it is also more costly. Conventional suturing, despite requiring more time, is a cost-effective alternative for laparoscopic appendicular stump ligation. The choice of technique may be guided by the available resources and surgeon's preference.

INTRODUCTION

Laparoscopic appendectomy, a minimal invasive surgical approach for the removal of an inflamed appendix, has become increasingly popular due to its advantages over open appendectomy, such as reduced postoperative pain, shorter hospital stay and quicker recovery[1]. A crucial step in this procedure is the secure ligation of the appendicular stump to prevent complications such as stump leakage and intra-abdominal abscesses. However, the optimal method for appendicular stump closure remains a subject of ongoing debate and research in the medical community. Historically, the methods for appendicular stump ligation have evolved significantly. The initial phases of laparoscopic appendectomy witnessed the use of techniques borrowed from open surgery, including hand-sewn closures. However, the technical challenges and time consumption associated with laparoscopic suturing led to the development and adaptation of newer methods[2]. These methods mainly include the use of endoscopic linear staplers, polymer clips, and loop ligatures.

Endoscopic linear staplers, which were introduced in the early 1990s, provide a rapid and reliable method of stump closure. They simultaneously cut and staple the base of the appendix, thereby minimizing the risk of leakage[3]. Despite their efficacy, the high cost of the staplers has been a point of concern, particularly in low-resource settings. Polymer clips, which are less expensive than staplers, have gained popularity due to their ease of use and cost-effectiveness. Studies have shown that polymer clips are associated with shorter operative times and lower overall costs, without compromising the safety of the procedure[4]. However, their applicability is limited by the diameter of the appendicular base and there are concerns about their security in cases of a friable or inflamed appendix.

Loop ligatures, or endoloops, offer a more cost-effective alternative to staplers. They are widely used due to their simplicity and reliability. However, the technique requires a certain level of skill to ensure a secure ligation and there are occasional reports of slippage and leakage[5]. Despite the availability of these methods, there is no consensus on the most effective and safe technique for stump closure. Several comparative studies have attempted to evaluate the efficacy, safety, and cost-effectiveness of these methods but results have been inconclusive or conflicting. A meta-analysis by Smith *et al*.[6] suggested that polymer clips are as safe as staplers, while another study by Gonzalez *et al*.[7] favored staplers for their lower complication rates. Similarly, the use of endoloops has been both supported and questioned in different studies[8,9].

Complication rates, particularly stump leakage and postoperative infections, are key indicators of the efficacy of stump ligation methods. Stump leakage, although rare, is a serious complication that can lead to peritonitis and abscess formation. The choice of ligation technique can significantly influence the risk of such complications. Studies have shown varying incidence rates of stump leakage, with some reporting higher rates with loop ligatures compared to staplers[10].

In addition to clinical outcomes, economic considerations play a crucial role in the choice of stump closure method, especially in resource-limited settings. The cost-effectiveness of a method is not only determined by the direct cost of the materials used but also by the operative time and the length of hospital stay, which are influenced by the ease and speed of the technique[11]. Given the variations in practice and the lack of a clear consensus, this study aims to conduct a comprehensive comparative analysis of the different methods of laparoscopic appendicular stump ligation. By examining clinical outcomes, complication rates, and cost-effectiveness, this study seeks to provide evidence-based guidance for surgeons in choosing the most appropriate method for stump closure during laparoscopic appendectomy.

Aims and objectives: The primary aim of this study was to determine the effectiveness of different methods used to ligate the appendix stump during laparoscopic appendicectomy. To achieve this aim the study was designed with specific objectives. Firstly, it assessed the reliability of various methods of stump ligation. Secondly, it evaluated the feasibility of these methods based on factors such as cost and technical aspects. Thirdly, the technical feasibility of each method was scrutinized. Lastly, a follow-up analysis of patients operated on using different methods was conducted to monitor outcomes and complications.

MATERIALS AND METHODS

This study, conducted at B.J.G.M.C. Pune, was an 18-month prospective observational study spanning from January 2019 to July 2020. It included patients diagnosed with appendicitis who met the inclusion criteria and were treated at the outpatient department (OPD) of this tertiary care hospital. The methodology involved identifying patients presenting to the hospital with symptoms suggestive of appendicitis. These patients underwent imaging, either Ultrasound or CT Abdomen and those with findings indicative of appendicitis were considered for surgery after providing written informed consent. Patients were thoroughly briefed about the different methods of appendicular stump ligation being investigated in the study, including the use of staplers, endoloops, and hand-made sutures. They were allowed to choose their preferred method based on factors like cost and

perceived reliability. Post-surgery, patients were followed up biweekly for a month through clinical examination and imaging to assess for complications and the overall recovery process.

Regarding the materials used the study employed standard laparoscopic instruments and apparatus. For the ligation of the appendicular stump, various materials were used, including suture material, endoloop and staplers. The selection of the sample was meticulously done. Inclusion criteria comprised diagnosed cases of appendicitis, selected cases of diagnostic laparoscopy and patients aged above 18 years. The exclusion criteria were set as patients under the age of 18 and those presenting with complicated appendicitis. The study ensured a comprehensive inclusion of diverse cases while maintaining strict criteria to exclude unsuitable subjects.

In terms of sample size the study enrolled 50 patients over the 18-month period to ensure a representative sample. The exact number was determined based on the flow of eligible patients to the hospital's OPD and the number of diagnosed appendicitis cases during the study period. This approach allowed for a robust analysis of the effectiveness and feasibility of the different methods of appendicular stump ligation, providing valuable insights into the optimal surgical technique for laparoscopic appendectomy.

RESULTS

The study encompassed a total of 50 patients who underwent laparoscopic appendectomy using one of three different suturing techniques Endoloop, Stapler, and Conventional Suture. The distribution of these techniques among the patients was as follows 22 patients (44%) underwent the Endoloop technique, 6 patients (12%) were treated with the Stapler method, and the remaining 22 patients (44%) received the Conventional Suture technique. In terms of gender distribution, of the 28 male patients, 13 (59.1%) were treated with the Endoloop method, 4 (66.7%) with the Stapler and 11 (50%) with Conventional Suture. Among the 22 female patients, 9 (40.9%) received the Endoloop method, 2 (33.3%) the Stapler and 11 (50%) the Conventional Suture. The p-value for gender distribution across the three suturing techniques was found to be 0.71, indicating no significant difference in the gender distribution among the different suturing techniques (Table 1).

The mean age of patients varied with the type of suturing technique used. Patients treated with the Endoloop method had a mean age of 32.64 years (SD = 13.007), those with the Stapler method had a mean age of 21 years (SD = 2.191) and the mean age for patients with Conventional Suture was 28.27 years (SD = 9.249). The overall mean age of the study group was 29.32 years (SD = 11.116). The difference in mean age across the three groups was marginally significant with a p>0.060.

In assessing the American Society of Anesthesiologists (ASA) Grade, it was observed that among the Endoloop group, 68.2% were Grade 1 and 31.8% were Grade 2. In the Stapler group, all patients (100%) were categorized as Grade 1. The Conventional Suture group had 95.5% in Grade 1 and 4.5% in Grade 2. The difference in ASA Grade distribution across the groups was statistically significant with a p>0.025.

The mean Body Mass Index (BMI) among the patients was relatively similar across the three groups: 21.04 kg m^{-2} (SD = 2.01) for Endoloop, 20.62 kg m^{-2} (SD = 2.49) for Stapler and 21.77 kg m^{-2} (SD = 2.13) for Conventional Suture. The overall mean BMI for all groups was 21.31 kg m^{-2} (SD = 2.12), with a p-value of 0.367, suggesting no significant difference in BMI among the groups. Regarding the duration of surgery, the Endoloop group had a mean duration of 92.5 min (SD = 12.9) the Stapler group 88.3 minutes (SD = 13.3) and the Conventional Suture group 98.6 min (SD = 11.8). The total average duration of surgery for all patients was 94.7 min (SD = 12.8), with a p-value of 0.119, indicating no significant difference in the duration of surgery among the different techniques.

The duration of suturing differed significantly among the groups, with the Endoloop group averaging 7.0 min (SD = 1.3), the Stapler group 5.7 min (SD = 1.2), and the Conventional Suture group 10.7 min (SD = 1.3). The overall mean duration of suturing was 8.5 min (SD = 2.4), with a p>0.0001, demonstrating a significant difference in the time taken for suturing among the three techniques. Post-operative pain, measured using the Visual Analogue Scale (VAS) at 6 hrs post-operation, showed little variation among the groups 2.41 (SD = 0.590) for Endoloop, 2.33 (SD = 0.516) for Stapler and 2.45 (SD = 0.596) for Conventional Suture. The overall mean VAS score was 2.42 (SD = 0.575), with a p-value of 0.898, suggesting no significant difference in early postoperative pain among the techniques.

The days required to resume work post-surgery were slightly different across the groups 6.32 days (SD = 0.780) for Endoloop, 5.33 days (SD = 0.516) for Stapler, and 6.14 days (SD = 0.774) for Conventional Suture. The overall mean was 6.12 days (SD = 0.799). This difference was statistically significant with a p-value of 0.024. Finally, in terms of cost analysis, the mean cost of raw materials for the Endoloop technique was 1500 currency units, significantly lower than the 6000 currency units for the Stapler technique. The Conventional Suture method had a mean cost of 620 currency units (SD = 73), indicating a significant difference in costs among the three techniques (p<0.0001) (Table 2-3).

Table 1: Patient demographics and surgical details

Variable	Endoloop (N = 22)	Stapler (N = 6)	Conventional Suture (N = 22)	Total (N = 50)	p-value
Gender					0.71
Male (Count,% within technique)	13 (59.1%)	4 (66.7%)	11 (50.0%)	28 (56.0%)	
Female (Count,% within technique)	9 (40.9%)	2 (33.3%)	11 (50.0%)	22 (44.0%)	
Mean Age (years)	32.64±13.007	21.00±2.191	28.27±9.249	29.32±11.116	0.060
ASA Grade				0.025	
Grade 1 (Count,% within technique)	15 (68.2%)	6 (100.0%)	21 (95.5%)	42 (84.0%)	
Grade 2 (Count,% within technique)	7 (31.8%)	0 (0.0%)	1 (4.5%)	8 (16.0%)	
BMI (Kg $m^{-}2$)	21.04±2.01	20.62±2.49	21.77±2.13	21.31±2.12	0.367

Table 2: Surgical and postoperative outcomes

Variable	Endoloop (N = 22)	Stapler (N = 6)	Conventional suture (N = 22)	Total (N = 50)	p-value
Duration of surgery (min)	92.5±12.9	88.3±13.3	98.6±11.8	94.7±12.8	0.119
Duration of suturing (min)	7.0±1.3	5.7±1.2	10.7±1.3	8.5±2.4	<0.0001
VAS at 6 Hrs post-Op	2.41±0.590	2.33±0.516	2.45±0.596	2.42±0.575	0.898
Days to resume work	6.32±0.780	5.33±0.516	6.14±0.774	6.12±0.799	0.024

Table 3: Cost analysis

Suturing technique	N	Mean cost of raw material (currency)	Std. deviation	p-value
Endoloop	22	1500	0	<0.0001
Stapler	6	6000	0	
Conventional Suture	22	620±73		

In summary, the results of this study highlighted significant differences in some aspects of the laparoscopic appendectomy procedures using different suturing techniques, particularly in terms of the duration of suturing, days to resume work and the cost of raw materials. However, there were no significant differences in other factors such as gender distribution, BMI, duration of surgery and early postoperative pain among the three suturing techniques.

Note: VAS = Visual Analogue Scale; BMI = Body Mass Index, ASA = American Society of Anesthesiologists, Std. Deviation = Standard Deviation, N = Number of Patients.

DISCUSSIONS

This study, conducted in a tertiary care center with 50 subjects diagnosed with acute appendicitis, focused on comparing three different techniques for laparoscopic appendicular stump ligation GIA stapler, endoloop and conventional suturing. Our findings revealed notable variations in certain aspects of the surgical procedure and postoperative outcomes, which are discussed in relation to existing literature. The gender distribution in our study (56% males and 44% females) is consistent with the findings of Chand *et al*.[12], who reported a similar distribution in their study population. The male to female ratio in our study was 1.22:1, indicating a slightly higher prevalence of appendicitis in males, aligning with the existing literature[1,2].

The mean age of our study population was 29.32±11.116 years, comparable to the 29.01 years reported by Chand, Singh, Kahlow *et al*.[12]. This similarity underscores the higher incidence of appendicitis in the second and third decades of life, often attributed to lymphoid hyperplasia in the appendix[13,14]. Our study's average BMI across all groups fell within the normal weight category (18.5-25 kg m^{-2}), aligning with the observations of other studies[15,16]. This uniformity across the groups minimized the potential impact of BMI as a confounding factor in surgical outcomes.

In terms of ASA grades, our distribution (84% in Grade 1 and 16% in Grade 2) reflects the general health status of patients typically undergoing laparoscopic appendectomy, indicating predominantly low-risk patients[17,18]. Regarding postoperative complications, our study observed a suture site infection rate of 2% and a knot slippage rate of 2% in the conventional suture group. These findings are slightly higher compared to those reported by Kiudelis *et al*.[19] and Mayir *et al*.[20], who found lower infection rates in similar groups. This discrepancy might be attributed to variations in surgical technique or patient characteristics.

The average time required for ligating the appendicular stump was significantly different across the three groups in our study, with the stapler group requiring the least time. These results are in line with Janczak[21], who also reported reduced operative time with stapler use. Our findings suggest that although the stapler method is more expensive, it offers the advantage of reduced operative time, which can be crucial in high-volume surgical settings. The cost analysis revealed significant differences among the techniques, with the stapler method being the most expensive. This finding is consistent with the literature, which often cites cost as a major factor in selecting the method of stump ligation[22,23].

This study contributes valuable insights into the ongoing debate regarding the optimal technique for laparoscopic appendicular stump ligation. While each method has its merits the choice often depends on a balance between cost, operative time and complication rates. Our results support the use of conventional suturing as a cost-effective and reliable option, particularly in settings where resources are limited. However, for surgeons prioritizing operative time, the stapler method, despite its higher cost, offers a quicker alternative.

CONCLUSION

This study, conducted in a tertiary center, involved 50 diagnosed cases of acute appendicitis, comparing laparoscopic appendicular stump ligation using conventional suture material, endoloop and GIA stapler. Our findings indicate no significant difference in overall postoperative hospital stay, pain and other complications across the three techniques. The stapler method, despite being costlier, required less operative time, averaging 88.3±13.3 min compared to 92.5±12.9 min for endoloop and 98.6±11.8 min for conventional suturing. The average cost was highest for the stapler group (6000 currency units) and lowest for conventional suturing (620±73 currency units). Although the conventional suture method is time-intensive, it remains an efficient and economical alternative, especially in settings where resources are limited. Our study suggests that while staplers and endoloops reduce the time to ligate the appendicular stump and hence the duration of surgery, they come with increased material and equipment costs.

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