ORIGINAL ARTICLE

Laparoscopic Appendectomy in Children

Use of the Endoloop vs the Endostapler

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Hypothesis: Two techniques are used for laparoscopic appendectomy (LA): division of the mesoappendix with the harmonic scalpel and ligation of the appendix with an endoloop (EL), or division of the mesoappendix and appendix with an endostapler (ES). Using an ES is a cost-effective technique that provides an outcome benefit in children who require appendectomy.

Design: Case series.

Setting: Academic, tertiary care children's hospital.

Patients: Seventy-five children who underwent LA from January 1, 2002, to March 31, 2004.

Intervention: Laparoscopic appendectomy.

Main Outcome Measures: Age, diagnosis, length of stay, surgical time, total operating room time, complications, and instrumentation costs were compared between the EL and ES groups.

Results: There was no significant difference in age, length of stay, perforated, gangrenous, or acute appendicitis diagnoses, or complications between the groups. The surgical time and total operating room time for LA in children in the ES group were significantly shorter than in children in the EL group by 15% and 17%, respectively ($P<.05$). The disposable equipment costs for LA were $201 per case in the ES group vs $400 per case in the EL group. The mean 14.9-minute increase in total operating room time in children in the EL group resulted in $373 of additional operating room and anesthesia costs. The decreased disposable equipment costs and shorter surgical time of LA in the ES group led to cost savings of $572 per case as compared with children who underwent LA with an EL.

Conclusions: There is no significant difference in outcome between children who undergo LA with an EL or with an ES. However, this study supports the use of the ES for LA as a more cost-effective technique that is associated with reduced surgical time.

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APPENDECTOMY IS ONE OF the most common surgical procedures. Since the introduction of endoscopic surgery to appendectomy in the early 1980s, laparoscopic appendectomy (LA) has been performed widely in adults and children. The procedure offers reduced postoperative pain, earlier recovery, shortened length of stay (LOS), and decreased intra-abdominal scarring.[1,2] Laparoscopic appendectomy can be performed safely and effectively using endoloops (ELs) or an endostapler (ES).[3,4] The benefit of LA in children continues to be controversial, particularly as it relates to surgical time (ST) and costs as compared with open appendectomy (OA).

A recent analysis[5] reported that the cost of pediatric LA for acute appendicitis is higher than the cost of OA in children. However, no cost distinctions were made between LA using an EL or ES, and most of the LAs were performed using an ES in that study. The cost of an EL is significantly less than that of an ES, and using an EL has been reported to reduce equipment costs by half when used instead of an ES.[6] If LA outcomes are equivalent between the techniques, then the use of an EL may be a more cost-effective technique, potentially offsetting the difference between LA and OA in children. We could not find a single article analyzing the outcome and costs of LA using ELs compared with the ES.

See Invited Critique at end of article

The specific aim of this study was to determine whether an outcome or cost benefit exists between the 2 techniques used for pediatric LA in our institution: division of the mesoappendix with the harmonic scalpel and ligation of the appen-

dix with an EL, or division of the mesoappendix and appendix with an ES.

METHODS

PATIENTS

We reviewed the records of children who underwent LA at the Children's National Medical Center, Washington, DC, between January 1, 2002, and March 31, 2004. Children undergoing incidental LA in operations for other indications as well as those whose cases were converted from LA to OA were excluded. Children who underwent interval LA following a course of complicated appendicitis were included. During laparoscopy for suspected appendicitis, it is our policy to perform LA of an uninflamed appendix if no other intra-abdominal pathological abnormality is detected. Such children were included in the study.

Children with all forms of complicated (gangrenous, perforated, periappendiceal abscess, intra-abdominal abscess) or uncomplicated appendicitis were included in the analysis. The pathology report took precedence over the operative notes for the description of the appendix.

PROCEDURES

All of the cases were treated at a tertiary care academic children's hospital. The children received the same preoperative antibiotics according to the institutional protocol. A disposable 12-mm port and two 5-mm ports (Ethicon Endosurgery, Cincinnati, Ohio) were used in both the EL and ES techniques.

The technique of LA with ELs was as follows. Pneumoperitoneum was created via the 12-mm port placed directly through the umbilicus. A suprapubic 5-mm working port and a left lower-quadrant 5-mm working port were placed. Following laparoscopic dissection, the mesoappendix was divided along the appendix with the harmonic scalpel. Two ELs (Ethicon Endosurgery) were placed at the base of the appendix, and the harmonic scalpel was used to ligate and divide the appendix distal to the ELs. The appendix was extracted from the abdomen via the 12-mm port. Rarely, the appendix was placed in an Endo Catch retrieval bag (Ethicon Endosurgery) if it was too large to fit into the 12-mm port or if significant spillage was anticipated during extraction.

The technique of LA with an ES was as follows. Pneumoperitoneum was created via the 12-mm port placed directly through the umbilicus. A suprapubic 5-mm working port and a subumbilical 5-mm working port were placed. Following laparoscopic dissection, a 35-mm ES (Ethicon Endosurgery) was used to divide the base of the appendix and mesoappendix. The appendix and mesoappendix were divided simultaneously with 1 staple load in most of the cases. The appendix was extracted from the abdomen via the 12-mm port. Rarely, the appendix was placed in an Endo Catch retrieval bag if it was too large to fit into the 12-mm port or if significant spillage was anticipated during extraction.

In all of the cases, if purulent material or abscess was present, it was evacuated and the pelvis and right paracolic gutter were irrigated. Children with uncomplicated appendicitis (acute, suppurative) received antibiotics for 24 hours and were discharged when they were afebrile, pain was controlled by oral agents, and the children could maintain their nutritional status. Children with complicated appendicitis were maintained as inpatients receiving intravenous antibiotics until they were afebrile for 24 hours, had a normal white blood cell count, had their pain controlled by oral agents, and could maintain their nutritional status. These children received antibiotics for a total of 14 days following discharge.

DATA COLLECTION

The ST and total operating room time (TT) were calculated from the operative report source document. In our institution, these times are determined by mutual agreement between the circulating nurse and anesthesiologist. The ST represents the time from the initial skin incision until the time that the dressings have been applied to all of the wounds. The TT represents the time from when the child was brought into the operating room until the time the child left the operating room following the procedure.

The LOS and incidence of complications were determined using the institution's electronic patient retrieval system. The electronic patient retrieval system allows for review of the entire inpatient hospital record and all outpatient clinic records at our institution and at the satellite facilities that are part of the Children's National Medical Center System. The electronic patient retrieval system was last accessed on December 8, 2004, for data on the groups of children; this provided for a minimum follow-up of 8 months. Follow-up data were available for all of the 75 children in the study.

Cost data for the ELs, harmonic scalpel, ES, and stapler reloads were provided by the hospital finance department. The costs were $375 for the harmonic scalpel handpiece, $25 for 2 ELs, and $201 for the 35-mm ES.

Cost data for anesthesia were provided by the anesthesiology department. The costs were $75 per 15-minute increment for the anesthesiologist fee and $20 per minute of operating room time.

STATISTICAL ANALYSIS

The χ^2 test was used to compare the discrete variables of diagnosis and complications in the 2 groups. The *t* test was used to compare the continuous variables of age, LOS, ST, and TT between the groups. Statistical significance was declared at $P<.05$.

RESULTS

The 2 groups were similar in terms of age, sex, weight, rate of complications, diagnoses (histologic features of the appendix), and LOS (**Table**). The mean±SD ST was 46.9±2.3 minutes in the group that underwent LA with an ES, which was significantly shorter than the mean±SD of 55.4±3.6 minutes in the group that underwent LA with ELs (mean difference, 8.5 minutes; $P<.05$). The mean±SD TT was 74.5±2.8 minutes in the group that underwent LA with an ES, which was significantly shorter than the mean±SD of 89.4±3.5 minutes in the group that underwent LA with ELs (mean difference, 14.9 minutes; $P<.05$).

The itemized costs of LA at our institution were considered to be the same between the groups, except for the ES in the ES group and the 2 ELs and the harmonic scalpel handpiece in the EL group. The equipment costs were $400 per case in the EL group and $201 per case in the ES group. The anesthesia cost was determined based on the mean difference in the TT. The mean difference in TT of 14.9 minutes resulted in an additional anesthesia cost of $373 per case in the EL group. The total unique operating and anesthesia costs were $773 in the EL group vs $201 in the ES group, a difference of $572. There were

Table. Characteristics of the Endostapler and Endoloop Groups

LA Technique	Patients, No.	Age, Mean ± SD, y	Patients With Perforated Appendicitis, No. (%)	LOS, Mean ± SD, d	Patients With Complications, No. (%)	ST, Mean ± SD, min*	TT, Mean ± SD, min†
ES	43	12.1 ± 0.54	18 (42)	3.2 ± 0.47	1 (2.4)	46.9 ± 2.3‡	74.5 ± 2.8‡
EL	32	13.7 ± 0.60	10 (32)	3.7 ± 0.72	2 (6.2)	55.4 ± 3.6	89.4 ± 3.5

Abbreviations: EL, endoloop; ES, endostapler; LA, laparoscopic appendectomy; LOS, length of stay; ST, surgical time; TT, total operating room time.
*The ST indicates the time from the initial skin incision until the time that the dressings have been applied to all of the wounds.
†The TT indicates the time from when the child was brought into the operating room until the time the child left the operating room following the procedure.
‡$P<.05$.

no deaths in either group. Two children in the EL group were readmitted for postoperative abscess. One child in the ES group required reoperation for an umbilical trocar-site hernia.

COMMENT

Laparoscopic appendectomy is one of the most common procedures performed by surgeons. The advantages of LA include reduced postoperative pain, earlier recovery, shortened LOS, decreased intra-abdominal scarring, and improved cosmesis.[1,2,6-8] Some prospective studies have shown increased hospital costs for LA as compared with OA[5-7] whereas others have found it to be less costly.[8,9] Increased hospital costs were related to prolonged operating time and the use of disposable instrumentation during LA. The challenge for health care providers is to reduce the direct operative costs (time and instrumentation) of LA to offset the cost difference of OA while maintaining the benefits of minimally invasive surgery.

As a result of the lack of published literature comparing the techniques of LA, the goal of this retrospective analysis was to compare the safety and outcome of the 2 most common techniques used by pediatric surgeons for LA, ES and EL. We examined 3 important variables between the 2 methods: ST, equipment costs, and LOS. While LOS is an important outcome parameter, it seems intuitive that a significant LOS difference between OA and LA may not exist. Length of stay may be more likely associated with the host response to the disease process and less with whether an open or minimally invasive technique was used. Therefore, the only factors that could be optimized are ST and instrumentation. We believe that our surgeons have mastered the operative learning curve and that the cost variance between LA and OA is largely a reflection of the instrumentation costs rather than ST. Ideally, LA should be performed using the technique that achieves the desired outcome as cost-effectively as possible. Although not addressed in our study, LA with an ES may challenge OA for overall cost-effectiveness, especially for older and obese children.

This study found that there is no difference in outcome between children who undergo LA with an EL and harmonic scalpel or with an ES. However, the instrumentation costs are higher in LA performed with the harmonic scalpel and EL technique. Reduced instrumentation costs, shorter anesthesia time, and shorter TT for children in the ES group resulted in an overall cost saving. Therefore, this study supports the use of the ES for LA as a cost-effective technique.

The results of this study are notable in that, to our knowledge, it is the first study comparing the techniques of LA in children. However, the lack of controls, the small numbers of patients, and the retrospective nature of this analysis may have limited the results. It is clear that the instrumentation costs are higher in LA with the harmonic scalpel and an EL compared with the ES. However, if electrocautery rather than the harmonic scalpel were used to divide the mesoappendix, the instrumentation costs would be significantly lower for LA with an EL ($25 vs $201, respectively). The harmonic scalpel is expensive, and substitution with electrocautery seems to be a logical alternative in terms of cost reduction. However, we must reflect on why the harmonic scalpel was developed. Multiple previous studies of the use of electrocautery during laparoscopy showed an association with collateral thermal injury to the bowel.[10-13] It is likely that electrocautery-associated bowel injury may be a learning curve issue because the use of an EL with electrocautery has recently been described as safe and effective.[14] It may be that the use of an EL with electrocautery further optimizes instrumentation costs for LA, but the safety factor requires additional analysis in children.

In terms of ST, the ST for LA with an ES in this study is equivalent to STs in other studies.[5] However, the ST for LA with ELs is greater than STs in other studies[3,10] using a similar technique. This may be a function of the additional technical skill required for LA with ELs and of the fact that all of the LAs performed in this study were done by junior surgical residents. There may be additional operating room time necessary for the setup and proper functioning of the harmonic scalpel. There are few studies to our knowledge comparing the technical aspects of the EL vs the ES. It appears in this small study and is a logical conclusion that the EL requires more technical expertise than the ES for the junior surgical resident. It is likely that LA with an EL performed by attending pediatric surgeons skilled in laparoscopy would reduce the time difference between the EL and ES techniques, resulting in similar operating room costs.

The costs of an EL vs an ES cannot be disregarded. In addition, the cost of a stapler reload should be considered. Although the mesoappendix and appendix can be transected using 1 staple load in children, this is likely

not the case in adult appendectomies. The current pressures and trends in health care financing have created a heightened need for effective and cost-efficient therapy. A logical approach may be selective use of the ES and EL. The goal would be to achieve a safe LA in less than 45 minutes. Laparoscopic appendectomy performed in equivalent times regardless of technique would result in cost savings for the technique using electrocautery and an EL. If it appears that the dissection and ligation of the mesoappendix is going to be time-consuming, then the ES technique may be a better option.

In conclusion, we found that LA using an ES in children is associated with reduced ST, TT, and instrumentation costs compared with using the harmonic scalpel and an EL. The reduced costs and ST resulted in cost savings in children who underwent LA with an ES. Therefore, in children, LA using an ES is a cost-effective therapy. A randomized trial comparing OA, LA with an ES, LA with an EL and harmonic scalpel, and electrocautery with an EL is indicated.

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