

# The Costs and Effects of Laparoscopic Appendectomy in Children

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**Background:** Laparoscopic procedures are performed commonly in children. In general, the cost containment of laparoscopic surgery in children has not been evaluated.

**Objective:** To compare the costs of laparoscopic appendectomy with those of open appendectomy.

**Design:** Prospective clinical trial between November 1, 1997, and April 30, 2000. For analysis, cost of supplies, operation room use, and recovery in the hospital and after discharge was evaluated. Costs common to both groups were not determined.

**Setting:** Operations performed in a university hospital.

**Patients:** Eighty-seven children aged 4 to 15 years who underwent appendectomy for suspected appendicitis. Patients were randomized to laparoscopic or open appendectomy.

**Intervention:** Laparoscopic appendectomies performed with the same standard set of reusable equipment.

**Main Outcome Measures:** Cost surplus of the laparoscopic procedure and recovery after surgery were evaluated, to determine the costs and effects of laparoscopic appendectomy compared with those of open appendectomy in children.

**Results:** Excess operating and complication costs per procedure were 96 euros (EUR) in laparoscopic appendectomy. The increased operative expenses were offset by a shorter hospital stay, resulting in a marginal difference of 53 EUR in itemized total costs between the 2 procedures (total cost, 1023 EUR in the laparoscopic appendectomy group and 970 EUR in the open appendectomy group). After laparoscopic appendectomy, children returned to school and sports earlier than those who had had an open appendectomy.

**Conclusion:** Laparoscopic appendectomy was marginally more expensive, but it allowed earlier return to normal daily activities than open appendectomy.

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LAPAROSCOPIC APPENDECTOMY (LA) has gained wide acceptance among pediatric surgeons, although its superiority over conventional open appendectomy (OA) is still to be determined. Because disposable instruments are used and the operative time is commonly longer, the laparoscopic procedure per se is more expensive than OA.<sup>1-3</sup> However, the cost-effectiveness of LA compared with OA is dependent on the relationship between excess total procedure costs and the recovery after surgery.

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Appendectomy is a common surgical procedure in children. Approximately 3 of 1000 children undergo appendectomy in Finland every year. Seventy children are operated on annually for acute appendicitis in Kuopio University Hospital, Kuopio, Finland, with a catchment area of 250 000 people.

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The aim of the present study was to evaluate the costs and effects of LA compared with OA in children. The costs were evaluated from the perspective of the health care payer. All direct costs related to the hospital treatment were itemized (listed in detail) to allow an economic comparison between laparoscopic and conventional techniques. Recovery after surgery was recorded to analyze the effects of laparoscopy.

## METHODS

The trial was conducted at Kuopio University Hospital between November 1, 1997, and April 30, 2000, and 87 children, aged 4 to 15 years, undergoing urgent appendectomy were studied. Children with a history of previous abdominal operations and those with asthma, kidney, or liver dysfunction; hemorrhagic diathesis; or neurologic disease were excluded. The study was approved by the local ethics committee and was conducted in accordance with the latest revision of the Declaration of Helsinki.<sup>4</sup> This report is a part of our Laparoscopic Appendec-

tomy in Children Study, and some results have already been published.<sup>5,6</sup>

### PROSPECTIVE CLINICAL TRIAL

The study design was prospective, randomized, and single-blind, with 2 parallel groups. After the decision was made to operate, children were selected randomly (by sealed envelope method) to undergo either LA or OA. Children, their parents, and research nurses were blinded to which procedure had been performed and remained blinded until the follow-up visit 7 days after the operation.<sup>5</sup> After the operation, each child had a similar wound dressing.<sup>5</sup> The anesthesia, analgesic treatment, and antibiotics used were standardized.<sup>5</sup> Laparoscopic procedures were performed by a pediatric surgeon (H.L.) who had experience with more than 30 LAs. Open procedures were performed by 13 surgeons, each of whom had experience with more than 200 OAs. A 3-port laparoscopic technique was used, and the appendiceal stump was secured with 2 polydioxanone ligatures (EndoLoop; Ethicon Inc, Somerville, NJ). The perforated appendix was removed with a plastic bag (Endocatch; US Surgical Corp, Norwalk, Conn). Open appendectomy was performed through a McBurney incision. Operating time (from skin incision to wound closure), anesthesia time (from anesthesiologists' arrival in the operating room to their leaving), and nurses' time (from beginning to arrange the operating room to leaving the room) were recorded. A standard discharge criterion was applied for both groups.<sup>5</sup> All appendixes were examined by a pathologist. Recovery at home was evaluated by a follow-up visit 7 days after the operation and by a telephone call 4 weeks after the operation.

### ANALYSIS OF COSTS

The direct costs related to the hospital treatment were calculated. The most important cost items (operation room times, bed-day costs, and costs of reoperation and readmission) were calculated for each patient. The fixed costs, such as the laparoscopic equipment, were calculated as the mean per patient. Data on staffing, equipment, materials, and drugs used in the trial were collected prospectively on a standard form.

For items of laparoscopic hardware and reusable instruments (Karl Storz Endoscopy, Tuttlingen, Germany), an estimate of their life span was obtained as well as an approximation of the number of times used. An annual equivalent cost was estimated and divided by the annual use to obtain a cost per patient. Valuation was carried out at year 2000 prices. The annual use of equipment was obtained from a hospital database in which all procedures from 1997 until 2000 were recorded. The same standard set of reusable instruments was also used in other laparoscopic procedures performed during the 2½-year trial. The amortization of reusable instruments was estimated at 150 cases. The monitor, camera, and light source were used in 130 laparoscopies, thorascopies, and arthroscopies per year, whereas the 5-mm Hopkins rod-lens telescope and insufflator were used in 60 laparoscopies per year. The hardware was assumed to be used for 6 years. The annual use of carbon dioxide was evaluated to estimate a cost per patient.

The consumption of analgesics and antibiotics was documented for each child, and the costs were calculated by the hospital pharmacy prices for 2000. Standardized antibiotics included only cefuroxime sodium, 80 mg·kg<sup>-1</sup>·24 h<sup>-1</sup>, and metronidazole hydrochloride, 20 mg·kg<sup>-1</sup>·24 h<sup>-1</sup>. The cost of inhalation anesthetics was calculated from the formula presented by Dion.<sup>7</sup> The cost of stay was calculated by multiplying the inpatient day price by the total inpatient length of stay. The fixed cost of an inpatient day was obtained from standard hospital statistics that included salaries of ward staff, capital

**Table 1. Patient Characteristics**

|                            | Laparoscopic Appendectomy (n = 43) | Open Appendectomy (n = 44) |
|----------------------------|------------------------------------|----------------------------|
| Sex, No. M/F               | 27/16                              | 27/17                      |
| Weight, mean ± SD, kg      | 42 ± 15                            | 45 ± 14                    |
| Height, mean ± SD, cm      | 148 ± 18                           | 151 ± 16                   |
| Age, mean ± SD, y          | 11 ± 3                             | 12 ± 3                     |
| Condition of appendix, No. |                                    |                            |
| Normal                     | 8                                  | 11                         |
| Suppurative or gangrenous  | 24                                 | 28                         |
| Perforated                 | 9                                  | 4                          |
| Abscessed                  | 2                                  | 1                          |
| Other abnormalities, No.*  | 3                                  | 0                          |
| Complications, No.         | 2 (Major)                          | 5 (Minor)                  |

\*One perforation of Meckel diverticulum, 1 omental necrosis, and 1 ovarian cyst rupture.

cost, and overhead expenses. Items of resource use were measured and valued in their naturally occurring units.

During LAs and OAs, the operating room was staffed by 1 surgeon, 1 anesthesiologist, and 3 nurses. Fixed basic salary was paid for operation room staff during regular working hours, while employees assigned to on-call duty were paid additional compensation for being placed on an on-call duty roster. A surgeon and anesthesiologist and the in-hospital nurses received the same on-call compensation for each hour of work irrespective of whether there was any active work. During night hours, one nursing team was in reserve to be called for urgent operations if several patients needed to be operated on at the same time. Each nurse in the reserve team received additional pay of approximately 5 euros (EUR) for each active hour of work.

The costs for operating room consumables, overhead property, administration, salaries of ancillary staff, anesthetic equipment, equipment maintenance, sterilization of the instruments, antibiotics, nonopioid analgesics, and anesthetics (except sevoflurane) were considered to be the same between LA and OA.

All adverse events were recorded for each child during 1 month of follow-up. Intraoperative and postoperative complications were added as a complication cost.

The cost excess of LA was estimated, and compared with savings associated with the length of hospital stay. Only the differences between the 2 techniques were considered, ie, the additional costs of laparoscopic equipment, complications, and length of postoperative hospital stay. Return to normal daily activities was evaluated to obtain cost-effectiveness of LA. Prices and wages were counted as euros (1 EUR=1 US dollar).

To compare the 2 study groups, continuous variables were analyzed by means of 2-tailed *t* test for 2 independent samples. For categorical variables, the  $\chi^2$  test and Fisher exact test were used. A *P* ≤ .05 was considered statistically significant.

### RESULTS

The 2 groups were similar in terms of age, sex, weight, height, rate of complications, and histologic features of the appendix (**Table 1**). The mean ± SD operating time was 42 ± 25 minutes in the LA group compared with 31 ± 14 minutes in the OA group (mean difference, 11 minutes; 95% confidence interval, 2-19 minutes; *P* = .02). The mean anesthesia time was 62 ± 25 minutes in the LA group and 51 ± 14 minutes in the OA group (mean difference, 11 minutes; 95% CI, 2-19 minutes; *P* = .02).

**Table 2. Total Procedure Costs per Patient Between Laparoscopic and Open Appendectomy in Euros\***

|                             | Cost, Euros               |                      |                          |
|-----------------------------|---------------------------|----------------------|--------------------------|
|                             | Laparoscopic Appendectomy | Open Appendectomy    | Mean Difference (95% CI) |
| Camera                      | 16                        | NA                   | NA                       |
| Light source                | 4                         | NA                   | NA                       |
| Monitor                     | 3                         | NA                   | NA                       |
| Telescope                   | 10                        | NA                   | NA                       |
| Insufflator                 | 17                        | NA                   | NA                       |
| Dissectors (2)              | 7                         | NA                   | NA                       |
| Scissors                    | 4                         | NA                   | NA                       |
| Cauterizing hook            | 1                         | NA                   | NA                       |
| Suction-irrigator setup     | 2                         | NA                   | NA                       |
| Trocars (3)                 | 3                         | NA                   | NA                       |
| Polydioxanone ties (2)      | 24                        | NA                   | NA                       |
| Other suture material†      | 4                         | 10                   | NA                       |
| Analgesics                  | 8 (SD, 7)                 | 12 (SD, 8)           | 4 (0.75 to 7.3)          |
| Specimen bag                | 10                        | NA                   | NA                       |
| Anesthetic gas              | 9 (SD, 2)                 | 7 (SD, 3)            | 2 (1 to 3)               |
| Carbon dioxide              | 1                         | NA                   | NA                       |
| Reoperation                 | 20                        | NA                   | NA                       |
| Readmission                 | NA                        | 18                   | NA                       |
| Hospital stay               | 880 (SD, 586)             | 923 (SD, 357)        | 43 (-163 to 250)         |
| <b>Itemized Total Costs</b> | <b>1023 (SD, 585)</b>     | <b>970 (SD, 402)</b> | <b>53 (-83 to 247)</b>   |

Abbreviations: CI, confidence interval; NA, not applicable.

\*Purchase prices of laparoscopic equipment (per unit, in euros [EUR]) were as follows: camera, 12 600 EUR; light source, 3340 EUR; monitor, 2510 EUR; telescope, 3690 EUR; insufflator, 6220 EUR; dissector, 530 EUR; scissors, 530 EUR; cauterizing hook, 168 EUR; suction-irrigator setup, 252 EUR; trocar, 168 EUR; polydioxanone tie, 12 EUR; specimen bag, 38 EUR.

†The same standard set of sutures was used in each procedure.

### LAPAROSCOPY COSTS

The itemized costs of the laparoscopic equipment per patient are presented in **Table 2**. The variance of the costs between children was small, ranging between 1 and 17 EUR per patient. Specimen bags (Endocatch) were used in 11 children with peritonitis. An endoscopic stapling instrument (Endo GIA; US Surgical Corp) was required in 1 child to resect a perforated Meckel diverticulum.

### WAGE COSTS OF THE RESERVE NURSING TEAM

The reserve nursing team was required for 3 LAs and for 3 OAs during night hours. Because the laparoscopic procedure took 27 minutes longer to perform than the open procedure, the nurses' time in the operating room was 89±35 minutes in the LA group compared with 62±17 minutes in the OA group ( $P=.001$ ); the mean difference in wage costs of the reserve nursing team was less than 0.5 EUR per patient between the 2 groups.

### RECOVERY IN THE HOSPITAL

There was a difference of 1 ampule per patient in the postoperative use of rescue analgesics (oxycodone [Oxanest; Leiras, Turku, Finland]) between the LA group and the OA group, resulting in a 4-EUR difference between the 2 groups.

The length of hospital stay, a mean of 2.8 days in the LA group and 3.0 days in the OA group, was multi-

plied by the mean cost of an inpatient day for a child with acute appendicitis, 310 EUR, resulting in a 43-EUR difference between the 2 groups.

### RECOVERY AFTER DISCHARGE

One child in the LA group had an enterocutaneous fistula of the residual appendiceal tip that needed open reoperation. The fixed cost of the relaparotomy was 850 EUR. The cost of this operation was derived from expenditure related to salaries of operating room staff, operative time, anesthesia time, equipment, etc. Another child in the LA group had a pelvic abscess that resolved with antibiotic treatment. In the OA group, an additional outpatient appointment costing 163 EUR per patient was required for 5 children with superficial wound infections.

### TOTAL COSTS

The difference in itemized total costs between the 2 procedures was 53 EUR (Table 2). Excess operating costs were 96 EUR per patient in the LA group, but the higher operative expenses were offset by a shorter hospital stay.

### COMMENT

In this study, a difference of 53 EUR in total procedure costs was found between LA and OA. This relatively small difference may be explained by the use of reusable laparoscopic instruments and slightly shorter hospital stay in the LA group. On the other hand, as reported earlier,<sup>5</sup> the children in the LA group returned to school 1 day earlier (after 7 days) than those in the OA group (8 days), and 5 days earlier to their normal sport activities (11 days vs 16 days after LA compared with OA). Therefore, LA seems to be more effective than OA in children.

Only a few studies have analyzed costs between LA and OA in children. Luks and coworkers<sup>8</sup> itemized all hospital costs for laparoscopic and open procedures and found that laparoscopy was cost-effective for appendectomy. In contrast, Little and coworkers<sup>3</sup> concluded that LA is more expensive and that it offers no obvious advantages compared with OA. However, the increased total costs per child undergoing LA were associated with a longer hospital stay.

Some prospective studies in adults have shown increased hospital costs for LA,<sup>9-13</sup> while others have found it to be less costly than OA.<sup>14,15</sup> Increased hospital costs were related to the prolonged operating time and the use of disposable instruments. On the other hand, Heikkinen et al<sup>16</sup> observed decreased total costs among employed adult patients undergoing laparoscopic procedure because they wanted an earlier return to work.

Reusable instruments may be used to control costs during endoscopic surgery. The amortized cost of laparoscopic instruments is markedly less than that of the systematic use of disposable instruments. It has been estimated that the cost of reusable trocars is 40 times less than that of the single-use equivalents.<sup>17</sup> Furthermore, according to Merhoff and coworkers,<sup>18</sup> the use of polydioxanone ligatures instead of a stapler may reduce equipment

costs by half. In our study, the amortization of laparoscopic reusable instruments was estimated at 150 cases because the same standard set of instruments was used during the whole 2½-year trial. The life span of laparoscopic hardware is expected to be between 5 and 10 years if used for 50 operations per year.<sup>19</sup> We have used our laparoscopic equipment now for 6 years. If the hardware had been estimated to be used for 10 years, the difference in costs between the 2 procedures would have been only 10 EUR. On the other hand, the fact that all LAs were conducted by a single surgeon may limit the generalizability of these findings to institutions where there is less expertise in pediatric laparoscopic procedures.

Most appendectomies in children are performed as urgent cases during on-call duty. Public hospitals should be adequately staffed regardless of whether there is any emergency work during night shift. While the urgent case block time may have relatively high utilization on one day, utilization would not be more likely to be high in the block on another day. On the other hand, the prolonged procedure time may result in extra costs in a situation in which an operating room is maximally utilized and staffed. However, in the present study, this was not the case because there was adequate unused operating room time during on-call duty.

Laparoscopic appendectomy may result in savings in indirect costs from shorter sick leave in adults.<sup>16</sup> It is more difficult to estimate the economic benefit of LA in children because, while the economic loss from an adult laid off from work can be measured, losses from a child being unable to attend school or participate in sports are not as economically apparent. The benefits to a child may be more related to quality of life. However, one of the most important advantages of LA may be that children can return to their normal activities earlier, thus saving parents the expense of child care and time off work.

Laparoscopic appendectomy required more resources than OA. However, LA was more effective, as the children returned earlier to their normal daily activities. In the standard thinking of cost-effectiveness analysis, the question about resource allocation is whether society is willing to pay a 53-EUR increase in costs per patient to ensure quicker recovery in children. Although LA required more resources per patient, the increment in total costs was small, so with reorganization of the work it meant only a minor increase in the use of hospital resources. From the societal point of view, the resource use outside health care should be included in the analysis. In our case, the most important resource use was the care at home after surgery. We had exact data only on health care costs (health care payer perspective), but if savings in resource use for care at home (parental loss of working time; the societal perspective) had been calculated and valued, they would very likely have been higher than the incremental health care cost of LA.

In conclusion, from the health care payer point of view, the laparoscopic technique seems to be marginally more expensive than the open technique. On the other hand, after LA children returned earlier to school and their sport activities. Because of differences in health care systems and in methods of economic evaluation, interpretations on an international level should be made cautiously.

### What This Study Adds

Laparoscopic appendectomy has gained wide acceptance among pediatric surgeons, although its superiority over OA is still to be determined. The purpose of this study was to compare the costs and effects of LA with those of OA in children.

Laparoscopic appendectomy is marginally more expensive than OA. After LA, children return to school and their sport activities earlier.

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