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Research Article

A COST-EFFECTIVENESS COMPARISON OF THE OPEN AND LAPAROSCOPIC APPENDECTOMIES FOR PEDIATRIC PATIENTS

***Amita Bhadauria**[1]*, ***Amogh Bhatnagar**[2]*

[1]Bradley University, Campus Town, Peoria, IL-61625, USA
[2]University School of Milwaukee, Milwaukee, WI 53217, USA
*Corresponding author: abhadauria@bradley.edu

Abstract: *Laparoscopic appendectomy (LA) is preferred to open appendectomy (OA), as it is less invasive. However, it is debatable whether LA is more cost-effective. We compared the cost-benefits of LA with OA, using the entire pediatric inpatient hospital data in the USA. The Kids' Inpatient Database (KID) shows that 51,007 pediatric patients were subjected to laparoscopic appendectomy and 12,668 to open appendectomy during 2010-12 across the USA. This dataset was used to assess the cost-effectiveness of LA and OA while controlling for the demographic characteristics of patients (e.g. age and gender), their background (e.g., place of residence), and complexity of surgery (e.g., number of procedures). We found that patients with laparoscopic surgery saved ~0.46 days of hospital stay, but paid $3641 more compared to patients with open surgery. Surgeons prefer to use the technologically advanced laparoscopic appendectomy (80% of patients). Our analysis shows that the cost-benefit of laparoscopic appendectomy is marginal. Hence, for making a fully informed decision, patients should be provided with both clinical and cost comparison data.*

Keywords: *open appendectomy, laparoscopic appendectomy, pediatric patient, economic cost, cross-sectional analysis.*

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1. Introduction

Since the introduction of laparoscopic appendectomy (LA) in 1983[1], numerous studies have been done to compare the clinical effectiveness of laparoscopic and open appendectomies (OA). LA involves a minimally invasive surgical procedure compared to OA, resulting in less pain, shorter hospital stay, fewer complications and better cosmetic outcomes [2-7]. While studies report that the average length of hospital stay after LA is marginally decreased compared to OA [8], LA increases the chance of incidence of the intra-abdominal abscess (IAA) in complicated appendicitis [9-12]. However, with advancements in technology and the technical proficiency of surgeons, LA is now extensively used in complicated appendicitis [13-15], where it confers significant benefits in terms of wound healing.

The surgical procedures for LA require skilled surgeons, extra operating time and advanced surgical technologies, thus increasing the overall cost. There is a long tradition of studies comparing LA with OA [16 - 33], and Table 1 summarizes some of the major studies from across the world. The last two columns compare the outcomes of the two procedures, the first one in terms of hospital stay and the second one in terms of hospital charges. We reviewed studies from countries as diverse as the US, Finland, China, Columbia, etc. We also studied research that was carried out in the last twenty years. The overwhelming consensus from around the world and for the last twenty years seems to be that LA is more expensive than OA, though it often leads to shorter hospital stay suggesting a quicker return to work and mobility.

Table 1: Literature Review

Study	The country where the study was carried out	Sample size	Did it study pediatric population?	Length of hospital stay was shorter after	Hospital charges were higher for
Martin et al. (1995)	USA	169	No	LA	OA
McCahill et al. (1996)	USA	162	No	No difference	LA
Richards et al. (1996)	USA	720	No	LA	No difference
Heikkinnen et al. (1998)	Finland	40	No	No difference	LA
Merhoff et al. (2000)	USA	-	No	No difference	LA
Long et al. (2001)	USA	198	No	LA	LA
Kurtz et al. (2001)	USA	758	No	LA	LA
Lintula et al. (2002)	USA	102	Yes	LA	Not studied
Ikeda et al. (2004)	Japan	100	Yes	LA	LA
Nguyen et al. (2004)	USA	60236	No	LA	No difference
Ignacio et al. (2004)	USA	52	No	LA	LA
Moore et al. (2005)	USA	Meta-analysis	No	Not studied	LA
Cothren et al. (2005)	USA	247	No	No difference	LA
Kehargias et al. (2008)	USA	293	No	LA	LA
Wei et al. (2010)	China	220	No	LA	No difference
Costa-Navarro et al. (2013)	Spain	142	No	LA	LA
Minutolo et al. (2014)	Italy	230	No	LA	No difference
Biondi et al. (2016)	Italy	593	No	LA	LA
Ruiz-Patino (2018)	Colombia	377	No	No difference	LA

This raises an intriguing question: does the additional cost of LA over OA justify the medical benefit? To address this question, we did a comparative and comprehensive analysis of the cost-effectiveness of LA and OA. While this type of investigation has been carried out by many other researchers, our study differs from the extant research in three crucial ways.

Patient recruitment is the most difficult and expensive aspect of any clinical study[34], including appendectomy[35], and therefore most clinical studies of appendectomy were conducted with small sample sizes (Please see the sample sizes of past studies in Table 1). This leads to selectivity bias because all demographic groups of patients and surgical complications were not adequately presented. Often, the larger retrospective studies are carried out with patients from one or two related hospitals, leading to controversial and contradictory outcomes. Of the twenty studies that we reviewed, only one had a large enough population [24]. To avoid the biases associated with small sample sizes, we analyzed the entire US pediatric population to assess the cost-effectiveness of LA and OA (over 3 million records).

Most studies involve adult subjects (please see Table 1). Of the twenty studies that we found, only one [13] focused on the pediatric population. Since children bodies are much smaller than adults, room for maneuvering the laparoscopic surgical equipment is much more limited, leading to a higher probability of side-effects, such as Intra-abdominal abscess (IAA). This constrains the advantages of LA. We focus exclusively on the pediatric population.

The outcome of surgical procedures would depend on patient characteristics. For instance, as children get older, their bodies grow and create more room to maneuver the laparoscopic surgical equipment, increasing the advantages of LA. We, therefore, used several control variables in our study that we believe would affect the success of LA, such as demographic characteristics of patients (e.g., age, gender, place of residence), day of surgical procedure (e.g., weekday and weekend), number of procedures (e.g., stitch or staple after surgical incision) and type of appendectomy (e.g., LA or OA).

There are three ways this research improves upon past studies. First, it focuses on the pediatric population, rather than the adult population. Second, it studies the entire US pediatric population as opposed to small sample size. Third, it controls for several patient characteristics.

2. Methods

Database: We used the Kid's Inpatient Database (KID), a member of the large family of healthcare databases developed for the Healthcare Cost and Utilization Project (HCUP). The HCUP-KID releases a vast amount of information on hospital inpatient stays of children (age <20 years) every three years. Here we focused our study on the 3 million patient records released from 2010-2012. During this period, 12,668 pediatric patients had an open appendectomy and 51,007 had a laparoscopic appendectomy. The ICD-9 procedure codes for open and laparoscopic appendectomy are 47.09 and 47.01, respectively.

From this dataset, the average length of stay in a hospital for each procedure was extracted. Typically, the duration of hospital stay is treated as a summary measure of recovery time with an assumption that patients are released from a hospital when they have attained the same level of recovery or pre-operative functional status[36]. Greater the operative or postoperative complications, the greater is expected to be the recovery time. We also extracted information on the total hospital charges from the billing discharge data.

Analysis of data: A number of factors, including patient demography, time of procedure and surgical complexities, are known to influence the treatment outcomes of appendectomy. For instances, Cheong and Emil (2014) show that the domicile status of patients is a determinant of the treatment outcome of appendectomy[37]. Al-Qurayshi et al. (2016) found that the complication after appendectomy depends on the day of the procedure (weekday or weekends)[38]. Tuggle et al. (2010) report that LA is superior to OA in term of wound infection[39]. Lee et al. (2011) concluded that among pediatric patients, older ones are more likely to have LA and males are more likely to have OA[8].

To determine the relationship between the length of hospital stay, hospital charges, and types of appendectomy, we had taken the above-mentioned factors (age, gender, place of residence, time of procedure and complexity of procedures) as controls. The relationship between dependent variables (i.e., length of hospital stay and hospital charge) and the independent variable (whether patient had LA or OA) and five control variables (age, gender, location of residence, number of procedures, and day of procedure) were tested by the following multiple linear regression equation[40].

$$Y_{im} = \alpha_m + \sum_n \beta_{mn} X_{imn}$$

where Y_{im} is the mth dependent variable for individual i. m can take only two values as there are only two dependent variables: length of hospital stay and hospital charges. n indexes the independent variables and X_{imn} is the nth independent variable for individual i. Here, α_m is the intercept for the mth dependent variable and β_{mn} are the corresponding regression coefficients.

3. Results and Discussion

31. Data descriptive statistics

Data of 63,695 patients who had uncomplicated or complicated appendectomies are described in Table 1. This analysis shows that the average length of stay in hospital was 3 days (standard deviation = 6.24 days), the average hospital charge was $35,498.00 (standard deviation = $65, 441), and more than four-fifth of patients (80.1%) were operated by laparoscopic procedures. The average number of procedures carried out on patients was 1.4. Nearly one-fourth of patients (25.7%) were admitted on weekends.

Table 2. Descriptive Statistics

Variable	Mean	St Deviation
Length of hospital stay	2.98 days	6.24 days
Total hospital charges	$ 35,497.73	$ 65,440.82
Age	12.62 years	4.86 years
Number of procedures	1.4	1.20
	Frequency	Percentage
Gender		
Male	37566	59.0
Female	26104	41.0
Admission day is a weekend		
No	47299	74.3
Yes	16376	25.7
Type of appendectomy		
Open	12668	19.9
Laparoscopic	51007	80.1
Place of Residence		
Central counties >= 1 million	21786	34.2
Fringe counties >= 1 million	14592	22.9
Counties pop: 250,000 -999,999	12894	20.2
Counties pop: 50,000 - 249,999	5303	8.3
Micropolitan counties	5436	8.5
Non-core counties	3473	5.5
Race		
White	30439	47.8
Black	3966	6.2
Hispanic	20414	32.1
Asian/Pacific Islander	1573	2.5
Native American	654	1.0
Other	3181	5.0

The KID data accurately represent a large patient population, ranging from newborn to 20 years old children, with an average age being 12.6 years. Nearly 60% of patients were male. More than one-third of patients were from large metropolitan areas. Patients were classified based on their residential location (Table 2). As expected, the proportion of patients located in a county goes down as the location of residence becomes more rural (e.g., 34.2% in the central county whereas 5.5% in the non-core counties). Nearly half the patients (47.8 %) were white and one-third were Hispanic (32.1%), with reasonable representation from other racial groups (see Table 2, bottom rows).

3.2. The relative length of hospital stay after open and laparoscopic appendectomies

The multiple linear regression model was used to determine the relationship between the length of the hospital stay and multiple variables such as type of appendectomy, age, gender, place of residence, day of procedure, and number of procedures (see Table 3).

Table 3. Length of Hospital Stay

	Regression Coefficient	Standard Error	t - stats	p value
Intercept	.519	.080	6.48	.00
Age in years at time of admission	-.144	.004	-36.69	.00
Whether admission day is a weekend (1=Yes, 0=No)	.021	.043	.48	.63
Gender (1=Female, 0=Male)	-.091	.038	-2.40	.02
Place of Residence	.039	.013	3.07	.00
Number of procedures	3.284	.016	204.73	.00
Laparoscopic (1=Yes, 0=No)	-.460	.048	-9.52	.00

Total number of observations: 63675
F stats: 8013.025 (sig: 0.000)
R square: 0.431

Here, we found that the intercept value was 0.519. Theoretically, it indicates that the length of hospital stay is 0.519 days for a male child (< 1-year-old), who had an open appendectomy without any medical procedure on a weekday in a county with a population greater than 1 million (metro area). As every patient must have at least one procedure, the actual hospital stay for the male child would be minimum 3.8 days (0.519 + the regression coefficient for Number of procedures = 3.284 with p-value <0.05). It also implies that the number of medical procedures has the greatest impact on the length of stay. For every increase in one procedure, the length of stay increases by 3.284 days. In other words, if everything else remains constant, a 10-year old child will stay in the hospital for 1.4 days less than a newborn, and a 20-year old person will stay for 2.8 days less than a newborn. Our analysis also suggested that the length of stay was more for patients in rural hospitals (regression coefficient = 0.039 with p-value <0.05), but had no effect on weekdays or weekend admission of patients (p-value > 0.63) as reported earlier [41]. Furthermore, our analysis suggests that for every increase of one year in a patient's age, the length of the hospital stay decreases by 0.144 days (regression coefficient = - 0.144 with p-value <0.05). The length of hospital stay was found to be significantly different when the procedure was laparoscopic. If everything else remains constant, patients with laparoscopic surgery spend 0.46 days less (regression coefficient = -0.46 with p-value <0.05).

3.3. The relative cost of open and laparoscopic appendectomies

Results from the regression model run on total hospital charges are presented in Table 4.

Table 4. Total Hospital Charges

	Regression Coefficient	Standard Error	t - stats	p-value
Intercept	-1750.589	910.643	-1.922	.06
Age in years at the time of admission	-537.492	44.586	-12.06	.00
Whether admission day is a weekend (1=Yes, 0=No)	1.351	486.508	.00	.99
Gender (1=Female, 0=Male)	-276.496	432.513	-.64	.52
Place of Residence	-1635.539	142.019	-11.52	.00
Number of procedures	32456.482	183.637	176.74	.00
Laparoscopic (1=Yes, 0=No)	3640.607	547.386	6.65	.00

Total number of observations: 63675
F stats: 5550.847 (sig: 0.000)
R square: 0.350

The intercept value was found to be zero (p > 0.05), suggesting that the hospital charges for a patient less than one year in age, undergoing open appendectomy with one procedure, and residing in a county with population greater than 1 million, would be $ 32,456 (see Table 4, number of procedures, regression coefficient = 32456.482). For every year increase in age, the hospital charges decrease by $537 (regression coefficient = -537.492 with p < 0.05). The gender of the patient and whether admitted on a weekday or weekend has no effect on the hospital charges (p > 0.05). Interestingly, the hospital charges were low among patients in rural hospital (regression coefficient = -1635.539 with p < 0.05). The number of procedures again has the largest impact on hospital charges (regression coefficient = -32456.482 with p < 0.05), suggesting that the cost of surgery increases with the increase of procedures. We found that the second biggest impact on hospital charges is from the type of procedure. If everything else remains constant, patients with laparoscopic surgery pay $3,640 more than patients with open appendectomy (regression coefficient = 3640.607 with p < 0.05).

3.4. The side effects of open and laparoscopic appendectomies

The frequency of occurrence of various side-effects associated with appendectomy are summarized in Table 5.

Table 5. Incidences of Side Effects

Side-effect	OA	LA	Total Incidences
Death	18 (0.1%)	0 (0.0 %)	18 (0.03 %)
Intra-abdominal abscess (IAA)	55 (0.4 %)	142 (0.3 %)	197 (0.3 %)
Paralytic ileus (PI)	854 (6.7 %)	2124 (4.2 %)	2978 (4.7 %)
Surgical site infection (SSI)	170 (1.3 %)	240 (0.5 %)	410 (0.64 %)

Total number of observations: 63675
The numbers in brackets are the percentages

During this period 18 deaths occurred exclusively among OA patients. However, death occurred only in 0.03% of the appendectomies. The most common side-effect was Paralytic Ileus (PI) that occurred in 4.67% of the appendicitis patients. PI occurs more commonly after OA (6.7%) compared to LA (4.2%). 1.3% of OA lead to surgical site infection as opposed to 0.5% for LA. Unlike the Paralytic Ileus and the surgical site infection, occurrences of IAA after OA and LA are 0.4% and 0.3%, respectively; suggesting that the occurrence of IAA is rare among appendicitis patients. Overall, it appears that OA is worse than LA in terms of side-effects, but the overall incidences of the different side effects are too small.

4. Conclusion

Multiple factors influence the clinical outcomes of appendectomies. These factors include patient's demographic features (e.g., age, gender and health status), their background (e.g., place of residence), day of surgical procedure (e.g., weekday and weekend), number of procedures (e.g., stitch or staple after surgical incision), and type of appendectomy (e.g., LA or OA). Using a large set of nationwide inpatient data, we systematically investigated how these multiple variables influenced the length of hospital stay and the associated health-care cost after appendectomies. Our studies showed that patients with laparoscopic appendectomy saved only 0.46 days of hospital stay (Table 3) and spent ~$3,640 more than patients with open appendectomy (Table 4). This extra-cost appears to be due to fees of skilled surgeons and expenses needed to operate and maintain the advanced surgical tools. Thus, it is a debate to choose the proper technique for an appendectomy.

Surgeons normally prefer laparoscopic surgery because it is associated with less pain, shorter hospital stays, fewer complications and better cosmetic outcomes (80% of the appendectomies were laparoscopic, Table 2)(4,10,42). Our analysis further showed that the number of laparoscopic appendectomies, between 2010 and 12, was 85% in metro (urban) counties and 67% in nonmetropolitan (rural) counties. This suggests that laparoscopic appendectomy has also been gradually replacing open appendectomy for the treatment of appendicitis in all counties, depending upon the availability of skilled surgeons, advanced tools and complexity of appendicitis. However, our analysis showed that the laparoscopic patients spent an extra ~$3,640. An obvious question is whether a shorter hospital stay (0.46 days) is really worth the extra cost. It is likely that some patients, particularly with low economic status, would prefer to stay in the hospital for an extra half-day to save $3640.

Due to the lack of data, we did not consider the 'unmeasured' benefits of the laparoscopic approach including post-operative pain and its psychological implications on the child population. The study also does not take into account the long term complications e.g. wound complications and their cost. However, this should not detract from the main contribution of this study – all surgical procedures should be compared to their costs as well as medical benefits.

Like appendectomy, laparoscopic surgery is routinely practiced to treat a large number of medical conditions, such as cholecystectomy[42] and hysterectomy[43]. Thus, the methodology demonstrated in this study can be used to compare any set of surgical approaches on both clinical outcomes and costs. At a time of rising health care costs, any strategy for the reduction of in-patient care expenditure should be of interest to patients, health care insurers, and policymakers.

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