Laparoscopic appendectomy for acute appendicitis is more favorable in the elderly, patients with comorbidities, and those with complicated appendicitis—a nation-wide population-based study

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Abstract

Introduction

Laparoscopic appendectomy (LA) for appendicitis is not routinely performed because the costs associated with that procedure are higher than those associated with open appendectomy (OA). However, few studies have investigated the economic influence of LA and OA on specific subpopulations, including the elderly, patients with comorbidities, and patients with complicated appendicitis. This population-based study was designed to investigate determinants of costs and LOS in patients undergoing appendectomy. Furthermore, we compared the differences in costs and LOS between LA and OA in various subpopulations.

Materials and Methods

We identified in-patients who underwent LA or OA for appendicitis during the period 2001 to 2008 from claims data obtained from Taiwan's National Health Insurance program. Costs and LOS were evaluated by multiple linear regression models in various subpopulations stratified according to age, number of comorbidities, and severity of appendicitis.

Results

Between 2001 and 2008, 22252 (13.3%) patients underwent LA and 144438 (86.7%) had OA. Age, comorbidity, and severity of appendicitis were determinants of costs and LOS for both LA and OA. Although costs and LOS for appendectomy increased with age and number of comorbidities, a sharper increase was noted in OA patients. LA mildly decreased LOS at the expense of significantly higher costs in young patients, those without comorbidities, and in patients with uncomplicated appendicitis. In contrast, when compared to OA, LA was associated with comparable costs and reduced LOS in the elderly, in patients with comorbidities, and in those with complicated appendicitis. In addition, hospital mortality and readmission rate for postoperative complication were not significantly different between LA and OA.

Conclusion

Considering costs and LOS, patients > 65 years, patients with comorbidities, and patients with complicated appendicitis benefit more from the laparoscopic approach for the treatment of appendicitis.

Key words:

Complicated appendicitis, elderly, comorbidity, cost, length of stay, laparoscopic appendectomy,

Introduction

Acute appendicitis is the most common disease requiring abdominal surgery, with an incidence of around 10 per 10,000 person years [1]. Based on this estimation, approximately 25,000 appendectomies are performed every year in Taiwan. For more than a century, open appendectomy (OA) via the McBurney incision has been the standard operation for acute appendicitis. However, laparoscopic appendectomy (LA) for treating acute appendicitis has been shown to be a safe and useful alternative for certain populations, such as morbidly obese patients and women of reproductive age [2-4]. Although LA is associated with shorter length of stay (LOS) and lower complication rates, its high cost precludes that procedure from replacing OA as the mainstream treatment of acute appendicitis in the general population [5-10].

As the population in our society ages, coexisting illnesses in the elderly are undoubtedly important factors in determining post-operative outcomes of patients with acute appendicitis. However, detailed studies comparing the costs and LOS associated with LA with those associated with OA for patients with appendicitis accompanied by underlying comorbidities have yet to be conducted. In addition, because the number of relevant cases is limited, only a few studies have investigated the difference in costs and length of stay between LA and OA in specific subpopulations, such as in the elderly and in patients with different severities of appendicitis. Furthermore, the results from those studies were often controversial [10-14]. The discrepancies in findings among the studies could be due to their small sample sizes and lack of adequate stratification or covariate adjustment by regression models.

Hence, we performed a comprehensive study to investigate determinants of adjusted hospital costs and LOS associated with LA and OA for acute appendicitis by analyzing a nation-wide population-based inpatient database. Furthermore, we compared the differences in adjusted costs and LOS between LA and OA for acute appendicitis in different subpopulations.

Materials and Methods

Study design

This study was a nationwide, retrospective, population-based analysis of insurance claims data from 23 million insured people obtained from Taiwan's National Health Insurance program via the National Health Research Institutes database. The National Health Insurance program in Taiwan is a universal insurance system established by the Bureau of National Health Insurance, Department of Health. The insurance program was implemented in March 1995, and by 1996 it covered more than 96% of the population [15]. The patient information that was recorded included all medical services received in 1996-2008, personal characteristics of patients, and characteristics of the physicians and hospitals. The patient identification numbers necessary to link files with identities were scrambled to ensure patient confidentiality. Thus, the ethical approval was not needed in this study. For this study, we utilized information including each patient's date of birth, sex, coexisting illness, main diagnosis and procedure at admission, hospital charge, LOS, accreditation level of the admission hospital, urbanization of the hospital's surrounding area, and discharge status.

Participants

All diagnosis and procedure codes were classified according to the International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM). Patients with a clinical diagnosis of appendicitis who received an appendectomy during the period 2001 to 2008 were identified from claims data in the National Health Insurance Research Database using ICD-9-CM codes (appendix A). Complicated appendicitis was defined as appendicitis with perforation, abscess formation, or peritonitis (ICD-9-CM 540.0 and 540.1). Patients with uncomplicated appendicitis were identified by ICD-9-CM diagnosis codes 540.9, 541, 542 (appendix A). Patients who received OA were identified by ICD-9-CM procedure codes 47.0 and 47.09, and those who underwent LA were identified by the ICD-9-CM code 47.01 (Appendix A). Patients of whom LA was converted to OA were incorporated into LA group based on the “intention to treat” principle. Patients with incidental appendectomy and patients with interval appendectomy were excluded from our analysis (Appendix A). Readmission for complication was defined as readmission with the diagnosis of commonly encountered postoperative complication within one month following appendectomy (Appendix B).

Outcome of measurement

Length of stay

The duration between admission and discharge dates was defined as the LOS (measured in days). LOS was recorded as 1 day in patients who were discharged on the same day they were admitted to hospital.

Hospital costs

The hospital costs were calculated by summing all items included in the hospital discharge summary, and included operation-associated costs and ward costs. Operation-associated costs included anesthesia and surgery fees as well as costs of medical supplies used during operation. The surplus costs were classified as ward costs. Costs expressed in this study are in US dollars (USD). In 2007, one US dollar was equivalent to approximately 32.64 Taiwan dollars.

Covariates

The covariates included age, gender, severity of appendicitis (complicated vs. uncomplicated appendicitis), number of comorbidities, hospital level (medical center, regional hospital, or district hospital), and urbanization level of the hospital's location (low, moderate, high). Hospital levels are defined by the Bureau of National Health Insurance as follows: "Medical center" is a large volume hospital which has at least 500 beds for emergency inpatient care and is also qualified as an academic teaching hospital. "Regional hospital" is a medium-sized teaching hospital which has at least 250 beds for emergency inpatients care. "District hospital" is a small volume teaching hospital with at least 20 beds for emergency care. The comorbidities evaluated in this study included myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, chronic pulmonary disease, rheumatologic disease, diabetes mellitus, and all malignancies (Appendix C). We chose to evaluate those comorbidities extracted from the Deyo-modified Charlson scale because they are the most commonly encountered coexisting illnesses in surgical patients [16, 17]. There are 319 townships and city districts in Taiwan. We calculated the population density (persons/km^2) by dividing the population by area (km^2) for each of those administrative units. The first quartile and the fourth quartile of population density were classified as areas of low and high urbanization, respectively. The second and the third quartiles of population density were considered areas of moderate urbanization.

Primary data analysis

The Student t-test was used to compare differences in patient characteristics, sociodemographic status, comorbidities, severity of appendicitis, hospital costs, and LOS between patients that received LA and patients that underwent OA. Second, to explore the effects of age and number of comorbidities on hospital costs and LOS following LA and OA, we demonstrated the unadjusted hospital costs and LOS according to the type of appendectomy and tested for linear trends according to age and the number of comorbidities. Third, we used multiple linear regression models to identify the linear effects of age and number of comorbidities on adjusted hospital costs and LOS separately for laparoscopic and open procedures. Finally, we compared the differences in costs and LOS between LA and OA among subgroups stratified by age (<65 vs. ≧65 years), presence of coexisting illness (comorbidity vs. no comorbidity), and severity of appendicitis (complicated appendicitis vs. uncomplicated appendicitis). A P-value < 0.05 was considered to indicate statistical significance; all tests were two-tailed. All analyses were performed with the statistical package SAS (Version 9.1, SAS Institute Inc. Cary, North Carolina, U.S.A.).

Results

Basal demographic results (Table1)

Unadjusted outcomes in the LA and OA groups (Fig.1a, b and Fig.2a,b)

Hospital costs

Length of stay

Determinants of adjusted hospital costs and LOS of LA and OA for appendicitis (Table 2)

Differences in adjusted costs and LOS between LA and OA stratified by age, comorbidity, and severity of appendicitis (Table 3)

According to the initial hospitalization records in 2001-2008, the numbers of patients who underwent OA and LA were 144,438 and 22,252, respectively. And, 55.4% of the 166,690 patients with appendicitis who underwent appendectomy were male (Table 1). LA patients were more likely to be hospitalized in a medical center than OA patients (49.4 % vs. 27.8%, p<0.001). Compared with OA patients, a higher proportion of LA patients lived in highly urbanized areas (84.1% vs. 74.7%, p<0.001). The average LOS was higher for OA patients than for LA patients (5.0 ± 0.02 vs. 4.0 ± 0.02 days, p<0.001). However, the average hospital costs were higher for LA patients than for OA patients (1178 ± 3 vs. 1042± 1 USD, p<0.001). There was no statistically significance in readmission rate (1.3% vs. 1.4%, p>0.05) and hospital mortality (0.01% vs. 0.04%, p>0.05) between LA and OA.

The unadjusted ward costs for OA and LA patients increased as age increased (both p values for linear trend were <0.001) (Fig. 1a). Ward costs associated with OA were lower than those for LA in populations < 65 years. In contrast, ward costs associated with OA were significantly higher than those for LA in patients ≧ 65 years. Furthermore, the discrepancy in unadjusted ward costs between OA and LA patients increased as age increased in patients ≧ 65 years (p for interaction <0.001). As for LOS, the unadjusted LOS associated with both OA and LA increased with age (p for linear trend <0.001); however, LOS in patients who underwent OA was always longer than that in patients who underwent LA (Fig. 1b). The discrepancy in LOS between OA and LA significantly increased with age (p for interaction <0.001).

The unadjusted ward costs of OA and LA increased with the number of comorbidities (both p values for linear trend <0.001) (Fig. 2a). Ward costs of OA were lower than those of LA in patients without comorbidities but were higher than LA in patients with comorbidities (p for interaction <0.001). Furthermore, the discrepancy in ward costs between OA and LA was greatest among patients with 2 comorbidities. Similarly, the unadjusted LOS of OA and LA increased with the number of comorbidities (p value for linear trend <0.001) (Fig. 2b). The discrepancy in unadjusted LOS between OA and LA patients varied among patients with different numbers of comorbidities and was greatest among patients with 2 comorbidities (p for interaction <0.001).

Coefficients in multiple linear regression models could be explained as differences in specific outcomes between the target group and the reference group; for example, adjusted costs of LA in patients aged ≥ 75 years were USD 207 more than those of LA in patients < 15 years (Table 2). In addition, the results of multiple linear regression models (Table 2) revealed that age, comorbidities, and the severity of appendicitis were determinants of adjusted costs and LOS in both LA and OA groups. We observed that the magnitude of the differences in coefficients of age for costs and LOS in both the LA and OA groups increased as the age increased (all p for linear trend <0.01). Furthermore, the magnitude of differences in coefficients of age for costs and LOS in LA patients was smaller than that in OA patients. Similarly, the magnitude of differences in coefficients of comorbidities for costs and LOS in LA and OA groups increased as the number of comorbidities increased (all p for linear trend <0.001). The magnitude of differences in coefficients of comorbidities for costs and LOS in LA patients was smaller than that in OA patients. These findings indicated that age and the number of comorbidities had a greater impact on costs and LOS for OA patients than for LA patients. In addition, costs and LOS associated with LA and OA for complicated appendicitis were higher than those for uncomplicated appendicitis. Furthermore, complicated appendicitis had a greater influence on increased costs and LOS for OA patients than for LA patients.

Table 3 presents differences in adjusted costs and LOS between OA patients and LA patients, stratified by various determinants. After multivariate adjustment, the adjusted costs for LA patients were significantly higher than those for OA patients < 65 years of age (US $146, p<0.001), for those without comorbidities (US $145, p<0.001), and for those with uncomplicated appendicitis (US $165, p<0.001). Alternatively, adjusted costs for LA patients were comparable to those for OA in patients ≥65 years of age, for those with one or more comorbidities, and for patients with complicated appendicitis. As for LOS, the adjusted LOS for LA patients was significantly shorter than for OA patients in all subpopulations. The effect of LA on shortening LOS was more significant in patients ≥65 years of age (1.8 fewer days, p<0.001), in those with comorbidities (1.5 fewer days, p<0.001), and in patients with complicated appendicitis (1.8 fewer days, p<0.001).

Discussion

We found that costs associated with the two procedures were comparable but that LA in patients > 65 years, in patients with comorbidities, and in patients with complicated appendicitis was associated with markedly shorter length of stay. Thus, those patient populations in particular benefit from the laparoscopic approach for the treatment of appendicitis. In contrast, for patients aged less than 65 years, for patients without comorbidities, and for patients with uncomplicated appendicitis, LA could be less beneficial due to a clinically insignificant reduction in LOS at the expense of substantially increased costs.

The proportion of patients undergoing LA (13.3%) was lower than that of patients receiving OA for acute appendicitis. However, the frequency of LA increased over time from less than 1 % in 2001 to 37.2% in 2008 (data not shown). The application of LA for the treatment of acute appendicitis has, therefore, gradually become more commonplace in Taiwan.

Advances in medical care increase life expectancy and as a result appendicitis in the elderly is commonly encountered in daily practice [18]. Studies have shown that LA for appendicitis in the elderly is a safe and efficient procedure because of its reduced overall postoperative complication rates and shorter LOS when compared to OA [19-21]. However, few of those studies were adjusted by adequate stratification or utilized regression models to rule out confounding influences from gender, comorbidity, hospital level, and the severity of appendicitis [19, 20, 22]. In addition, few studies have evaluated the differences in costs and LOS between LA and OA among different subpopulations.

Our results demonstrate that, in comparison with OA, elderly patients (≧65 years) undergoing LA have comparable hospital charges, mainly due to reduced ward costs, and shorter adjusted LOS. Thus, elderly patients with appendicitis could benefit more from the laparoscopic approach than younger patients. Moreover, such advantages of LA over OA can be expected to conserve more medical costs in developed countries where charges for ward services are high. One possible explanation for the superiority of LA is that laparoscopy provides a more accurate diagnosis and thorough clearance of intra-abdominal soiling for complicated appendicitis, a condition commonly encountered in elderly patients. Subsequently it avoids unnecessary ward costs and LOS due to infectious complications resulting from residual intra-abdominal abscess and wound infection [13, 20, 23].

Elderly patients not only tend to have poor physiological reserve, but also have more comorbidities, which may cause higher rates of morbidity and mortality following the treatment of appendicitis [23, 24]. However, most previous studies did not use age and comorbidity as independent covariates to separately evaluate their influences on costs and LOS associated with surgical treatment for acute appendicitis [13, 19, 20]. In addition, chronic diseases such as diabetes mellitus and ischemic heart disease are gradually becoming more common in young populations, mainly as a result of increased fat and salt intake as well as lack of adequate exercise [25, 26]. Our results show that comorbidity was an independent determinant of costs and LOS in patients undergoing appendectomy for acute appendicitis. Patients with comorbidities benefit more from LA for the treatment of appendicitis because that procedure is associated with lower LOS. On the contrary, LA was less favorable in patients without comorbidities because the reduced

LOS did not outweigh the substantially increased costs associated with the procedure. Our findings provide a novel opinion on the choice of operative methods for acute appendicitis in young patients with comorbidities.

It is well known that it costs more to treat complicated appendicitis than simple appendicitis. However, the superiority of LA over OA in reducing hospital costs and LOS for patients with complicated appendicitis is still inconclusive based on the results of many small population-based studies because these studies often lacked adequate subpopulation stratification or covariate adjustment [3, 11-14, 27-29]. Nonetheless, Sporn et al. found that LA was associated with shorter adjusted LOS but higher costs compared to OA [10]. Of particular interest, they found that such increases in adjusted costs for LA were less significant in patients with complicated appendicitis than in those with uncomplicated appendicitis (adjusted cost for LA was 22% higher than that for OA in uncomplicated appendicitis but only 9% higher in complicated appendicitis) [10]. Consistent with their results, our study also showed that the adjusted costs for LA were higher than OA in uncomplicated appendicitis (USD 165, $p<0.001$). In contrast, LA was associated with statistically significant but clinically insignificant higher costs for patients with complicated appendicitis. Furthermore, our study also showed that LA is more effective than OA in reducing the LOS in patients with complicated appendicitis (1.8 days shorter, $p<0.001$). Thus, patients with complicated appendicitis could benefit more from LA than from OA. In general, those well-documented advantages of LA in the treatment of complicated appendicitis, namely reduced wound complications and less pain, may have played a role, both in our study and in Dr. Sporn's study [11, 27, 28, 30] .

There were several limitations in our study. First, the Bureau of National Health Insurance only collects in-hospital cases based on ICD-9-CM codes for disease and procedures. Error in coding is possible in such a large population-based database. Second, detailed information on operation time, patients' physical status at admission (i.e. body weight and hemodynamic status), as well as laboratory data were not available in the database. Because of those limitations, we could only investigate the influence of operative methods on costs and LOS for patients with acute appendicitis, although we were able to use regression models to adjust for confounding influences, including age, gender, admitting hospital level, comorbidity, and severity of appendicitis to determine the advantages of LA versus OA. We were unable to evaluate other clinically important outcomes such as operation time, postoperative complications, postoperative pain level, cosmesis, postoperative recovery time, and the time of returning to work. Furthermore, we were unable to identify those patients who managed their complications on an ambulatory basis from our database. Nonetheless, those complications that could be treated at home should be minor ones and would not significantly affect our conclusion. Finally, treatment for delayed complications after appendectomy for acute appendicitis could increase total costs and LOS. However, the incidence of readmission following appendectomy was comparable between the LA and OA groups of patients (LA vs. OA= 1.3% vs. 1.4%). Hence, the influence of readmission due to delayed complications following appendectomy could be ignored.

To summarize, in terms of hospital costs and LOS, elderly patients, patients with comorbidities, and patients with complicated appendicitis could benefit more from LA for the treatment of appendicitis. Nevertheless, more prospective investigations should be designed to address the true economic advantages of LA, such as the time of returning to work and normal daily activity.

Conclusion

Using data from a nation-wide health insurance database, we compared the costs of and LOS associated with laparoscopic appendectomy with those associated with open appendectomy for the treatment of acute appendicitis. Our results suggest that the costs of LA are comparable to those of OA but that LOS is shorter, especially for elderly patients over 65 years of age, patients with comorbidities, and those with complicated appendicitis.

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Authors Disclosure

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Figure legends:

Fig.1a: Unadjusted operation and ward costs vs. different age groups. Ward costs for both LA and OA increased as patients' age increased (both p for linear trend were <0.001). Discrepancy of ward costs between OA and LA increased with increasing patients' age, particularly for those beyond 65 year-old (p for interaction <0.001). LA: laparoscopic appendectomy, OA: open appendectomy.

Fig.1b: Unadjusted mean hospital length of stay (LOS) after appendectomy vs. different age groups in patients with appendicitis. LOS for both LA and OA increased as patients' age increased (both p for linear trend were <0.001). Discrepancy of LOS between OA and LA increased with increasing age (p for interaction<0.001). LA: laparoscopic appendectomy, OA: open appendectomy.

Fig.2a: Unadjusted average operation and ward cost vs. the number of comorbidities. Ward costs for both LA and OA increased as patients' comorbidity increased (both p for linear trend were <0.001). Ward costs of OA were less than that of LA in patients without comorbidity but higher than LA in those with comorbidities (p for interaction <0.001). LA: laparoscopic appendectomy, OA: open appendectomy.

Fig. 2b: Unadjusted length of stay (LOS) of OA and LA vs. the number of comorbidities in patients with appendicitis. LOS increased with the increasing number of comorbidities in both OA and LA group (both p values for linear trend were <0.001). Difference of LOS between OA and LA differed in groups with different numbers of comorbidities and was largest in those with 2 comorbidities (p for interaction <0.001). LA: laparoscopic appendectomy, OA: open appendectomy.

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