Research Article

Laparotomy Versus Laparoscopy Cholecystectomy for Surgical Treatment in Patients with Gallstone Disease: A Comparative Cost-Effectiveness Analysis

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Abstract

Background: Due to the increasing costs of the healthcare system and limited financial resources, healthcare policymakers should adopt more cost-effective strategies.

Objectives: This study aimed to compare the cost-effectiveness of laparotomy cholecystectomy with laparoscopy.

Methods: This economic evaluation was conducted on patients with cholecystitis who were candidates for surgery in a private hospital in Ahvaz in 2021. Data collection tools consisted of four parts: (1) demographic information checklist; (2) clinical information checklist; (3) cost checklist; and (4) effectiveness assessment tool. SPSS[22] and STATA[14.2] were used for data analysis. One-way sensitivity analysis and Tornado diagrams were performed using Tree Age software.

Results: The mean total effectiveness score in patients treated with laparoscopy was 83.44 (SD = 11.34), which was higher than those treated with laparotomy at 68.39 (SD = 13.61). This difference was statistically significant in all effectiveness criteria, except for postoperative infection rates and length of operation ($P < 0.001$). The mean cost for patients undergoing laparoscopy was significantly higher than for those undergoing laparotomy ($481.43 vs. $459.49). However, overall, laparoscopic treatment (5.77) was more cost-effective than laparotomy (6.71). The laparoscopic procedure was approximately $1.47 per effectiveness unit cheaper than laparotomy, according to the ICER. One-way sensitivity analysis showed that the laparoscopic method remained more cost-effective, even when adjusting for cost and effectiveness components.

Conclusions: Although laparoscopic cholecystectomy was more expensive than laparotomy cholecystectomy, it was generally more cost-effective. The results of this research may assist Iran's healthcare policymakers and managers in promoting laparoscopic cholecystectomy in hospitals.

Keywords: Cholecystectomy; Laparoscopy; Laparotomy; Sensitivity Analysis; Cost-Effectiveness

1. Background

Gallstone disease is relatively common in humans, with its prevalence varying by country (1). It is one of the leading causes of emergency room admissions, presenting a significant global health issue and economic burden (2). According to World Health Organization (WHO) reports, the estimated global incidence and death of gallbladder disease in 2022 were 122491 and 89055, respectively. Asia accounted for the highest number of cases in all categories compared to other continents (3).

Gallbladder resection is the only definitive treatment for gallstones, and until 1986, it was performed exclusively through open surgery by splitting the abdominal wall (4). Today, laparoscopy is a widely accepted technique, even for acute gallbladder inflammation, and can be safely performed in patients with hernias, abdominal ascites, or during pregnancy (5). The advantages of laparoscopic cholecystectomy include shorter hospital stays, reduced postoperative pain, lower risk of infection and incisional hernia, faster recovery, quicker return to daily activities, and improved cosmetic outcomes with less scarring compared to open cholecystectomy (6).

However, despite its benefits, laparoscopic cholecystectomy can result in complications. Major complications include severe bleeding, surgical wound infections, bile leaks, bile duct injury, bowel and liver injury, pneumoperitoneum (air introduced into the peritoneal cavity for better visibility during surgery), and gallstones spilling into the abdominal cavity, potentially leading to abscess formation. Many of these complications arise from the limited visibility during laparoscopic surgery. The occurrence of these complications often depends on the surgeon's skill. The most serious complication, bile duct injury or stenosis, occurs in 0.4 to 0.6% of patients. Despite these risks, most physicians consider laparoscopy the preferred method for patients with symptomatic gallstones (7-11).

Certain conditions, such as a history of upper abdominal surgery, can complicate laparoscopic cholecystectomy. In general, the risk of bile duct injury is higher in laparoscopic cholecystectomy compared to laparotomy cholecystectomy (12).

Due to the increasing costs in the healthcare system and limited financial resources, a cost-effective strategy with the highest possible effectiveness is essential. Currently, economic analysts in the health sector use the comprehensive term "economic evaluation" to describe a set of tools that assist decision-makers in evaluating various technology applications from an economic perspective (13). Real-world decision-making is complex and involves external considerations beyond economic evaluations, such as justice and fairness, intangible benefits and costs, feasibility, and other factors.

Economic evaluation plays a crucial role in decision-making (14). Worldwide, economic evaluations of medical procedures are widely conducted to ensure that treatments are worth their costs (15). In cost-effectiveness analysis, costs are measured in monetary terms, while outcomes are measured and compared in effectiveness units. A fundamental question in cost-effectiveness analysis is whether the costs of programs or procedures are justified by their outcomes (16, 17).

Cost-effectiveness analysis assesses the ability of a process to achieve its goals relative to the costs incurred. It examines how efficiently a particular product or service can be delivered at the lowest possible cost. Although the cost-effectiveness of various surgical procedures has been studied in Iran, no research has specifically addressed the cost-effectiveness of cholecystectomy surgeries.

2. Objectives

Given the high prevalence of cholecystectomy in the country, we designed a study to analyze the cost-effectiveness of laparoscopic versus laparotomy cholecystectomy among patients with gallstones in a private hospital in Ahvaz, Iran.

3. Methods

3.1. Study Design and Population

This observational economic evaluation study aimed to compare the cost-effectiveness of two methods of cholecystectomy: Laparoscopy and laparotomy. The study population consisted of patients who underwent cholecystectomy by either laparoscopic or laparotomy methods in 2021 at a private hospital in Ahvaz.

3.2. Sample Size and Sampling Method

The sample size for this study was determined based on the research of Lammert and Sauerbruch (18) and was calculated using the formula for comparing means, considering a 95% confidence interval. To calculate the sample size, a first type of error of 0.05 and a power of 80% were used. In the formula, the standard deviations were set as S1 = 3.6 and S2 = 9, and the difference between the means was set as 4.

$$n = \frac{\left(z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2 \times (s_1^2 + s_2^2)}{(\overline{x_1} - \overline{x_2})^2}$$

The formula is as follows:

Patients were divided into two groups using simple random sampling. The sample consisted of 62 patients undergoing laparotomy cholecystectomy and 62 undergoing laparoscopic cholecystectomy. The cost in this study was examined from the patients' perspective, and the direct costs were calculated based on the hospital bills. The patients were randomly selected from those who underwent cholecystectomy surgery at a private hospital between January and March 2021.

The study was conducted in two steps:

Step 1: Evaluating effectiveness: The effectiveness of the surgeries was assessed based on the opinions of five surgeons at the hospital. The effectiveness indices included the length of hospital stay, time to return to work, pain, surgery duration, and post-surgery infection. Patients were followed up for one month after treatment to assess time lost before returning to normal activities or work. Additionally, to calculate the total effectiveness of the surgeries, five surgeons were asked to assign weights to each effectiveness index. The weight of each index was calculated based on total scores (ranging from 0 to 100).

Step 2: Cost analysis: Costs such as those for the surgeon, operating room supplies, assistant surgeon, anesthesia, and hospital stay (hoteling) were extracted from the patients' bills. All costs were converted to US dollars using the Purchasing Power Parity (PPP) for 2021 (19).

3.3. Inclusion and Exclusion Criteria

Patients over 18 years of age with a diagnosis requiring cholecystectomy, who were referred to the hospital for surgery between January and March 2021, were included in this study. However, patients whose type of surgery was changed from laparoscopy to laparotomy during the admission period due to medical reasons were excluded from the study.

3.4. Data Collection Tools

Data were collected using a questionnaire consisting of three parts. The first part focused on demographic information (e.g., age, gender, marital status, education status, income). The second part addressed costs, including surgeon fees, operating room supplies, assistant surgeon fees, anesthesia, and hoteling expenses. The third part pertained to effectiveness components (e.g., pain, days of hospitalization, duration of surgery, days to return to work, and infection). Information related to effectiveness was obtained through interviews with patients. During the interviews, patients were asked to complete an informed consent form and provide their address, contact number, and other necessary demographic details.

Additionally, cost-related information, the length of hospital stay, time to return to work, pain (assessed using the VAS questionnaire), and surgery duration were retrieved from the patient records. For the infection index, recurrence within 48 hours after discharge and the presence of infection symptoms (e.g., fever), as diagnosed and recorded by the doctor in hospital records, were considered as indicators.

3.5. Statistical Analysis

We used SPSS22, STATA14.2, and Tree Age software for data analysis. Frequency distribution tables, related graphs, mean, standard deviation (SD), mean difference (MD), Cohen's d, independent t-tests, and ANOVA were applied to compare the costs and effectiveness of the two surgical methods. A decision tree model was designed, including Laparoscopy (LC) and Laparotomy (LP) branches as strategies. As shown in Figure 1, we considered subbranches for complications that resulted in infection treatment and discharge, and no complications, which led to patients being discharged on time (illustrated in Figure 1). For economic evaluation, a Tornado diagram, along with one-way and two-way sensitivity analyses, was used with Tree Age software.

For the sensitivity analysis, all parameters were adjusted within a predetermined range (± 30% for costs and ± 10% for effectiveness) from baseline values to assess the model's sensitivity, visualized through a Tornado graph. We used the 2020 PPP international dollar as the exchange base, with Iran's Gross Domestic Product (GDP) per capita, PPP (current international $), being $15,791, based on World Bank records. This GDP per capita served as the cost-effectiveness threshold for the analysis.

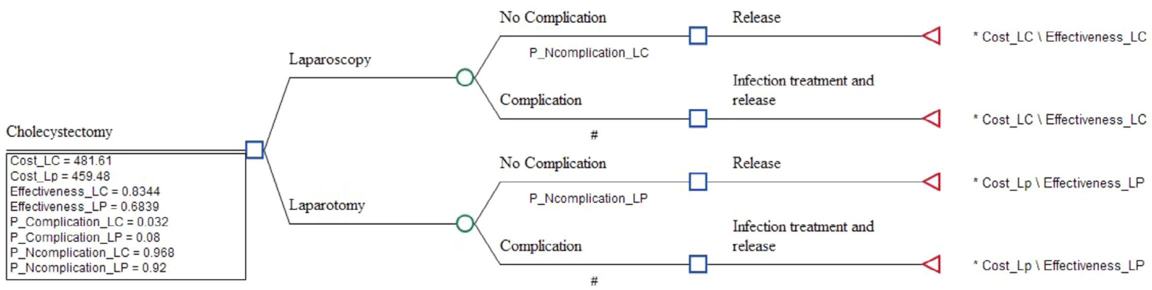

Figure 1. Decision tree for laparoscopy and laparotomy

SPSS 22 was used for further data analysis. Frequency distribution tables and related graphs (for qualitative data) and means with standard deviations (for quantitative data) were used to describe the data. The independent t-test and ANOVA were used for comparing the mean values.

The incremental cost-effectiveness ratio (ICER) is a key concept in evaluating the cost-effectiveness of health interventions. It represents the additional cost of an intervention per additional unit of health gain compared to an alternative intervention. In other words, the ICER quantifies the incremental cost of a new intervention relative to the existing standard of care, expressed in terms of the additional health benefits it provides. The ICER was calculated using the formula Δ COST / Δ EFFECTIVENESS.

3.6. Ethical Consideration

This study was approved by the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences (Reference No: IR.AJUMS.REC.1399.791). Before conducting the research, the researchers were formally introduced to the hospital by the Vice-Chancellor for Research and Postgraduate Studies. The study's objectives were thoroughly explained to all participants, and written informed consent was obtained. Participants were assured that their information would remain anonymous and confidential. Participation was entirely voluntary, and participants were informed that they could withdraw from the study at any time without any consequences. The researchers adhered strictly to ethical principles throughout the data collection, analysis, and final reporting processes.

4. Results

The demographic characteristics of the participants are shown in Table 1. The mean age of patients undergoing laparoscopy and laparotomy was 34.74 years (SD = 1.38) and 35.41 years (SD = 1.37), respectively. In terms of income, 51% of participants had a monthly income of less than 105 US$, 35% had an income ranging from 106 to 210 US$, and only 15% had a monthly income exceeding 211 US$.

Table 1. Demographic Characteristics of Participants

Factors and Levels	Laparoscopy (N = 62)	Laparotomy (N = 62)	P-Value
Gender			0.72
Male	28 (45)	30 (48)	
Female	34 (55)	32 (52)	
Age, median (IQR)	34.0 (26.0, 42.0)	34.0 (28.0, 42.0)	0.71
Marital Status			0.57
Married	40 (65)	43 (69)	
Single	22 (35)	19 (31)	
Education			0.28
Up to high school	36 (58)	30 (48)	
College education	26 (42)	32 (52)	

[a] Values are expressed as No. (%).

The mean costs of laparoscopy and laparotomy are shown in Table 2. According to the independent t-test, a significant difference was observed between the costs of the two treatment procedures. Additionally, the results of the calculated standardized mean difference (SMD) using Cohen's d indicated a significant difference between the two surgical methods. The mean total costs for the laparoscopy procedure were higher than those for the laparotomy procedure. The SMD for total costs was estimated at 0.38 (95% CI: 0.02 to 0.73), indicating a weak effect size for the mean difference (MD).

Table 2. Mean Costs of Laparoscopy and Laparotomy

Costs and Type of Treatment	Obs.	Mean; (US $)	SD	Std. Err.	Mean 95% CI	t	P-Value	Mean Diff. (Laparoscopy – Laparotomy)	MD 95% CI	SMD (Cohen's d	SMD 95% CI
Surgeon						3.67	< 0.01	28.03	12.90 to 43.17	0.66	0.30 to 1.01
Laparoscopy	62	226.65	32.77	4.16	218.33 to 234.97						
Laparotomy	62	198.62	50.50	6.41	185.80 to 211.44						
Essential equipment						45.03	< 0.01	44.50	42.54 to 46.46	8.09	7.01 to 9.16
Laparoscopy	62	82.82	4.72	0.60	81.62 to 84.02						
Laparotomy	62	38.32	6.18	0.79	36.75 to 39.89						
Assistant surgeon						-13.88	< 0.01	-13.47	-15.40 to -11.55	-2.50	-2.97 to -2.02
Laparoscopy	62	47.64	4.79	0.61	46.42 to 48.86						
Laparotomy	62	61.11	5.95	0.76	59.60 to 62.63						
Anesthesia						3.00	< 0.01	1.90	0.65 to 3.16	0.54	0.18 to 0.90
Laparoscopy	62	30.22	3.78	0.48	29.26 to 31.18						

Laparotomy	62	28.31	3.25	0.41	27.48 to 29.14						
Hoteling						-7.05	< 0.01	-38.83	-49.72 to -27.94	-1.27	-1.65 to -0.88
Laparoscopy	62	94.28	30.10	3.82	86.64 to 101.93						
Laparotomy	62	133.12	31.18	3.96	125.20 to 141.03						
Total costs (except hoteling)						7.91	< 0.01	60.96	45.71 to 76.21	1.42	1.02 to 1.81
Laparoscopy	62	387.33	33.22	4.22	370.89 to 395.77						
Laparotomy	62	326.36	50.76	6.45	313.47 to 339.25						
Total						2.11	0.03	22.13	1.40 to 42.87	0.38	0.02 to 0.73
Laparoscopy	62	481.61	49.33	6.26	469.09 to 494.14						
Laparotomy	62	459.48	66.10	8.39	442.69 to 476.27						

Furthermore, the mean Length of Stay (LoS) for laparoscopy patients was significantly lower than that for laparotomy patients, with a mean of 2.69 days (SD = 0.86, 95% CI: 2.47 to 2.91) versus 3.91 days (SD = 0.92, 95% CI: 3.68 to 4.15), respectively. Consequently, hoteling costs were not considered, and only the surgical procedure costs were compared. This led to a mean cost difference of over 60$. Cohen's d results for the surgery procedure indicated a very large effect size, with an SMD of 1.42 (95% CI: 1.02 to 1.81).

Table 3 presents the mean effectiveness scores across different dimensions based on the type of procedure. Cohen's d indicated a very large effect size (SMD) for effectiveness between laparoscopy and laparotomy in the "pain," "days for returning to work," and "Length of Stay (LoS)" subscales. In contrast, the "duration of surgery" and "infection" subscales did not show significant differences, and their SMD was not considerable.

Table 3. Mean Scores of Effectiveness in Different Dimensions by Type of Procedure

Effectiveness and Type of Treatment	Obs.	Mean ± SD	Std. Err.	Mean 95% Cl	t	P-Value	Mean Diff. (Laparoscopy – Laparotomy)	MD 95% CI	SMD (Cohen's d)	SMD 95% CI
Pain (30 points out of 100)					5.40	< 0.001	7.25	4.60 to 9.92	0.97	0.60 to 1.34
Laparoscopy	62	23.47 ± 6.15	0.78	21.91 to 25.03						
Laparotomy	62	16.21 ± 8.61	1.09	14.02 to 18.40						
Length of stay (10 points out of 100)					8.60	< 0.001	2.27	1.75 to 2.80	1.54	1.14 to 1.94
Laparoscopy	62	8.50 ± 1.61	0.20	8.09 to 8.91						
Laparotomy	62	6.22 ± 1.32	0.19	5.89 to 6.56						
Days for back to work (20 points out of 100)					5.06	< 0.001	3.71	2.26 to 5.16	0.91	0.54 to 1.28
Laparoscopy	62	13.39 ± 3.81	0.48	12.42 to 14.36						
Laparotomy	62	9.68 ± 4.33	0.55	8.58 to 10.78						
Duration of surgery (10 minute) (10 points out of 100)					0.98	0.33	0.29	-0.29 to 0.88	0.18	-0.18 to 0.53

Laparoscopy	62	7.48 ± 1.81	0.23	7.02 to 7.94						
Laparotomy	62	7.19 ± 1.47	0.19	6.82 to 7.57						
Infection (30 points out of 100)					1.16	0.25	1.45	-1.02 to 3.92	0.21	-0.14 to 0.56
Laparoscopy	62	29.30 ± 5.34	0.68	27.68 to 30.39						
Laparotomy	62	27.58 ± 8.24	1.05	25.49 to 29.67						
Total effectiveness (100 points out of 100)					6.69	< 0.001	15.05	10.59 to 19.50	1.2	0.81 to 1.58
Laparoscopy	62	83.44 ± 11.34	1.44	80.56 to 86.32						
Laparotomy	62	68.39 ± 13.62	1.72	64.94 to 71.85						

The mean LoS for patients who underwent laparoscopy was 2.6 days (SD = 0.9), compared to 3.7 days (SD = 0.9) for patients who underwent laparotomy. This difference was statistically significant (P < 0.001), as determined by the two-sample t-test. The median (IQR) LoS for patients undergoing laparoscopy was 2.0 days (2.0, 3.0), while it was 4.0 days (3.0, 5.0) for those undergoing laparotomy.

The mean number of days for returning to work after laparoscopy was estimated at 6.0 days (SD = 1.7), while for those undergoing laparotomy, it was 7.6 days (SD = 1.8). This difference was statistically significant (P < 0.001). The median (IQR) time to return to work following laparoscopy was 6.0 days (5.0, 7.0), compared to 8.0 days (6.0, 9.0) for laparotomy patients.

Figure 2 illustrates the cost-effectiveness graph comparing the two strategies. The tornado diagram (Figure 3) shows that the cost-effectiveness results were highly sensitive to cost parameters of the two strategies. Additionally, the incremental cost-effectiveness ratio (ICER) presented in Table 4, along with the one-way sensitivity analysis in Figure 4, indicates that for costs less than 481.61 Int. $, laparoscopy is the dominant strategy. However, for costs exceeding this value, the cost-effectiveness result does not change. In other words, laparoscopy remains the more cost-effective and effective procedure compared to laparotomy.

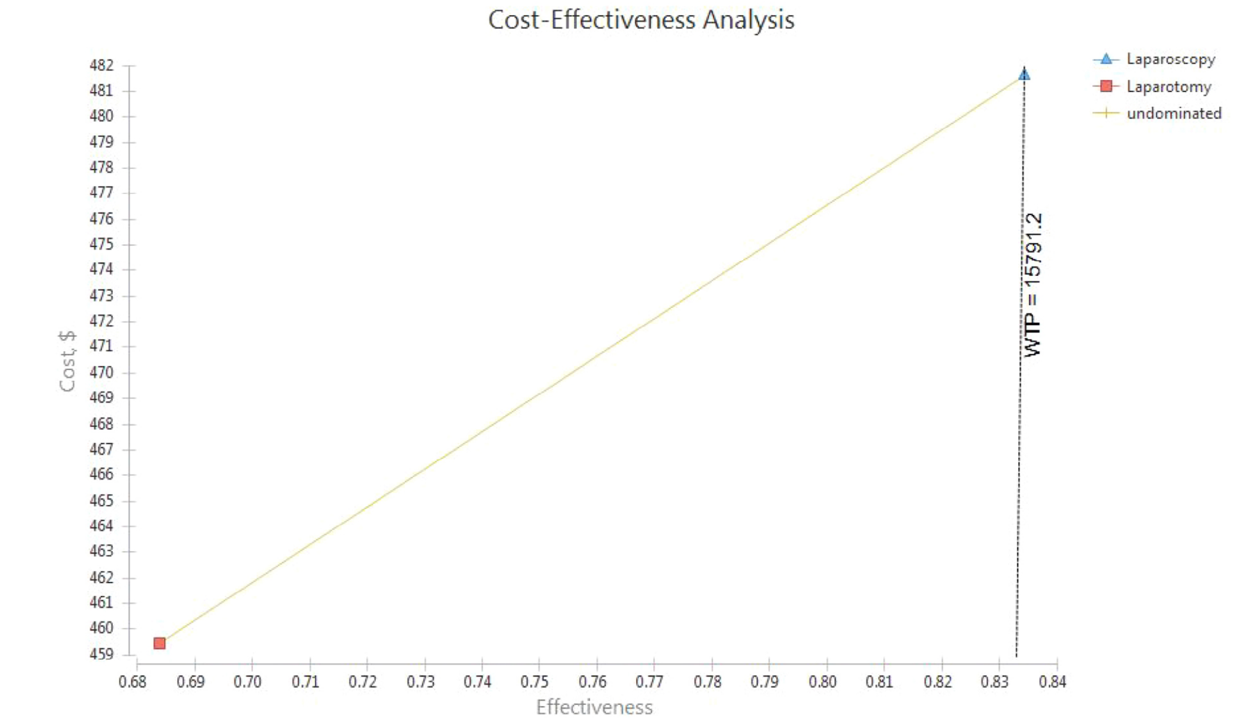

Figure 2. Laparoscopy and Laparotomy Cost-Effectiveness Analysis (cost: Int. $)

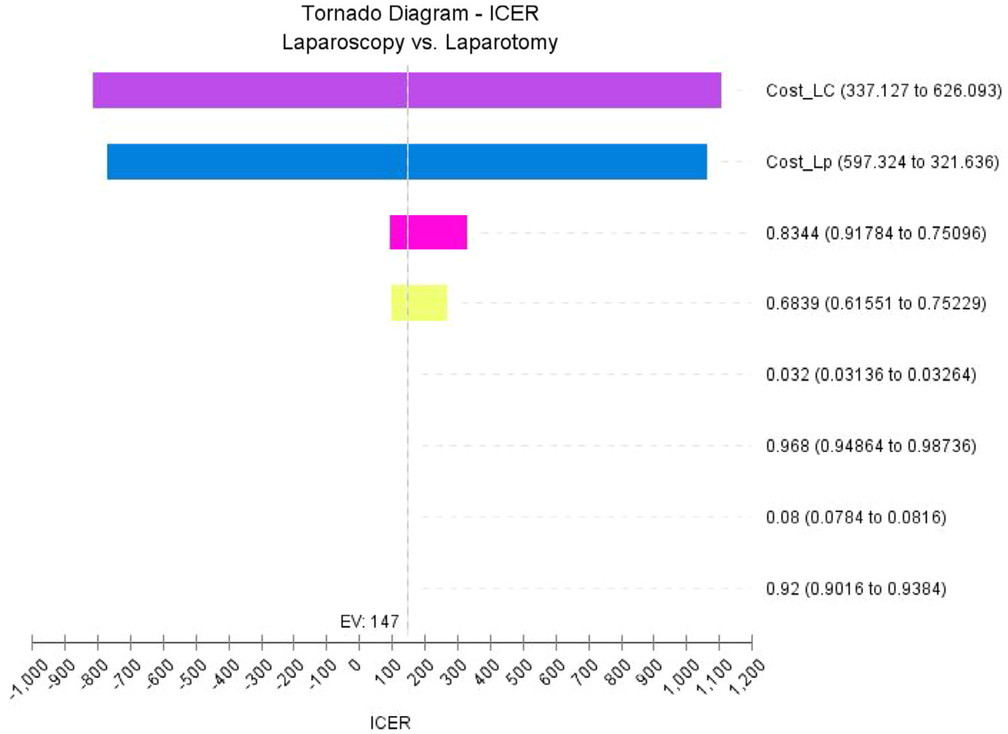

Figure 3. Incremental cost-effectiveness ratio (ICER) Tornado diagram for Laparoscopy and Laparotomy

Table 4. Incremental Cost-Effectiveness Ratio

Type of strategy	Total cost (Int. $)	Effectiveness	Cost-Effectiveness	Δ Cost	Δ Effectiveness	ICER
Laparoscopy	481.61	83.44	5.77	22.13	15.05 %	147.04
Laparotomy	459.48	68.39	6.71			

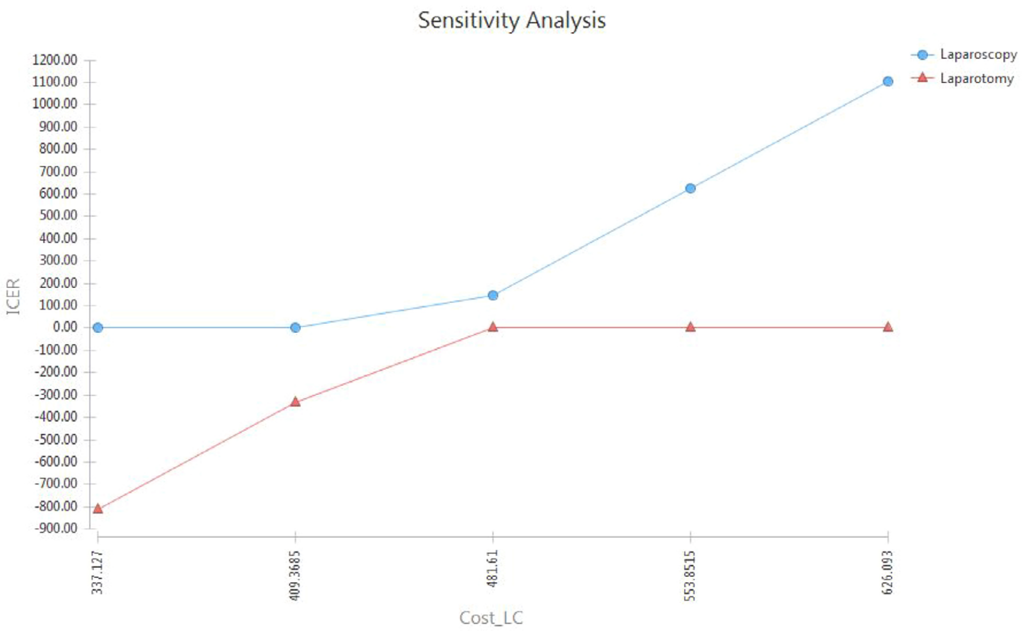

Figure 4. One way sensitivity analysis graph for laparoscopy and laparotomy

For the two-way sensitivity analysis, we simultaneously adjusted the costs of both strategies within a predetermined range (± 30%) based on the tornado chart (Figure 5). The results revealed that the cost-effectiveness outcome is not sensitive to simultaneous changes in both parameters, confirming that laparoscopy remains the cost-effective strategy.

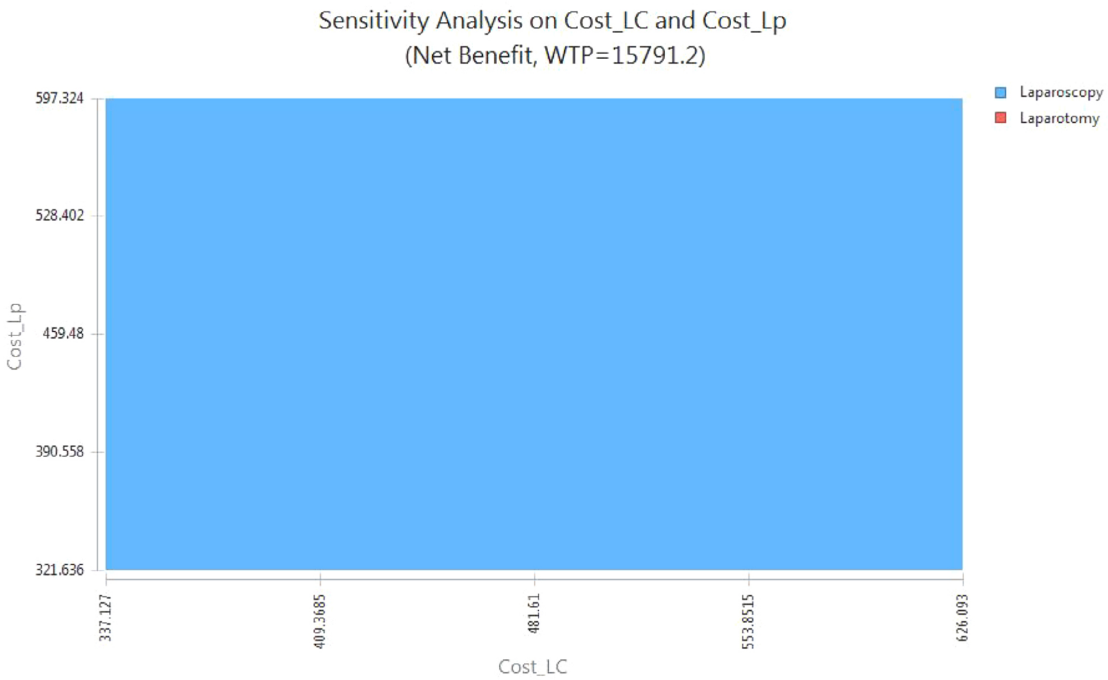

Figure 5. Two-way sensitivity analysis graph for laparoscopy and laparotomy

5. Discussion

This study aimed to compare the cost-effectiveness of laparotomy cholecystectomy versus laparoscopy. Our results showed that the mean cost for patients undergoing laparoscopy was significantly higher than for those undergoing laparotomy. Although laparoscopy was more expensive, it proved to be more effective in all evaluated criteria. Ultimately, laparoscopic cholecystectomy was found to be more cost-effective than laparotomy. Therefore, the decision regarding which type of surgery to choose should be based on a mutual discussion between the physician and the patient, considering their preferences. The findings from our study align with other studies that have reported an economic advantage when using laparoscopic techniques for various conditions (20-25).

In terms of effectiveness, we found that the length of hospital stay and the time to return to work were significantly shorter for patients who underwent laparoscopic surgery compared to those who underwent laparotomy. Additionally, patients who had laparoscopy reported experiencing less pain, which is likely due to the smaller incisions required for this procedure. Furthermore, while the laparoscopic procedure incurs higher costs due to the need for specialized surgical instruments, surgeon expertise, and required training, these expenses are partially offset by the higher hoteling costs associated with laparotomy patients. This contributes to the overall greater cost-effectiveness of laparoscopy.

Similar results have been reported in previous studies comparing these two methods for other diseases. Across all studies, patients who underwent laparoscopy had shorter hospital stays and returned to daily activities sooner than those who underwent laparotomy (20-22, 24, 26). Compared to traditional laparotomy, laparoscopic surgery is more widely accepted and offers benefits such as smaller incisions, reduced pain, shorter hospital stays, quicker recovery, less intraoperative blood loss, and fewer complications (27-29).

According to the one-way sensitivity analysis, the results were not sensitive to any of the effectiveness variables, including infection, length of hospital stay, time to return to work, pain, and duration of surgery. Changing each of these variables had no effect on the overall cost-effectiveness. Furthermore, as shown by the tornado diagram, although the surgeon's fee played the largest role in the total cost, removing any of the cost factors (e.g., surgeon fees, assistant surgeon fees, operating room consumables, anesthesia, and hoteling) did not alter the overall cost-effectiveness.

5.1. Limitations

Our study has several limitations. First, indirect costs were not estimated, which could provide a more comprehensive view of the cost-effectiveness. Second, due to the short follow-up period, long-term surgical complications, such as hernias and adhesions, were not considered. Third, while our findings are similar to results from other surgeries performed via laparotomy and laparoscopy, they cannot be generalized to all surgeries due to differences in the nature of surgical procedures. Finally, the results are limited to private hospitals, which may not reflect the broader healthcare system.

5.2. Conclusions

Our results indicate that although laparoscopic cholecystectomy was more expensive than laparotomy, it was generally more cost-effective. The findings suggest that implementing laparoscopic cholecystectomy would provide substantial health benefits to patients at a reasonable additional cost to the healthcare system. Adopting this intervention could lead to improved patient outcomes and a more efficient allocation of limited healthcare resources. These findings may assist Iran's health system policymakers and managers in promoting the use of laparoscopic cholecystectomy in more hospitals. Further research is needed to validate these results across different patient populations and healthcare settings.

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Conflict of Interests: The authors declare that they have no competing interests.

Data Reproducibility: Data will be available upon reasonable request from the corresponding author.

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