Laparotomy versus laparoscopy cholecystectomy for surgical treatment in patients with gallstone disease: a comparative cost-effectiveness analysis

Hamed Abdollahi
1. School of Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.

Farzad Faraji-Khiavi (faraji-f@ajums.ac.ir)
2. Department of Health Services Management, School of Public Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.

Nayeb Fadaei Dehcheshmeh
3. Department of Public Health, Shoushtar Faculty of Medical Sciences, Shoushtar, Iran.

Mohammad-Hossein Haghighzadeh
4. Department of Statistics and Epidemiology, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.

Research Article

Keywords: Cholecystectomy, Laparoscopy, Laparotomy, Effectiveness, Sensitivity analysis, Cost-effectiveness

Posted Date: November 17th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2200773/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

**Background:** Due to the increasing costs of the health system and limited financial resources, healthcare policymakers should apply more cost-effective strategies. This study aimed to compare the cost-effectiveness of laparotomy cholecystectomy with laparoscopy.

**Methods:** This economic evaluation was performed on patients with cholecystitis who were candidate for surgery in a private hospital in Ahvaz, southwest of Iran, in 2021. Data collection tools consisted of 4 parts: 1) demographic information checklist; 2) clinical information checklist; 3) cost checklist (e.g., costs related to a surgeon, operating room supplies, surgeon assistance, anesthesia and hoteling) and 4) effectiveness assessment tool (e.g., pain questionnaire and questions related to hospital days, duration of surgery, days of return to work and infection). We used SPSS22 and STATA14.2 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 83.44 (SD = 11.34) was higher than those treated with laparotomy 68.39 (SD = 13.61). This difference was statistically significant in all effectiveness criteria except for postoperative infection dimensions and length of operation (P-value <0.001). The mean cost in patients undergoing laparoscopy was significantly higher than those undergoing laparotomy (481.43 $ VS 459.49 $), but overall laparoscopic treatment (5.77) was more cost-effective than laparotomy (6.71). The cost-effectiveness of the laparoscopic procedure was approximately 1.47 $ per effectiveness unit cheaper than laparotomy, according to the ICER. According to one-way sensitivity analysis, the laparotomy method was still more effective by changing the cost and effectiveness components.

**Conclusion:** Although laparoscopic cholecystectomy was more expensive than laparotomy cholecystectomy, it was generally more cost-effective. The results of this research may help Iran's health system policymakers and managers in order to extend laparoscopic cholecystectomy in more hospitals.

Introduction

Gallstone is a relatively common disease in humans, and its prevalence is known to vary by country [1]. Gallstone is the most common risk factor for admission to the emergency room, imposing a significant worldwide health issue and economic burden [2]. According to WHO reports, the total number of incidence, deaths and 5-year prevalence resulting from gallbladder worldwide in 2020, in both sexes, was estimated at 115, 949, 84 695 and 137, 466, respectively. Asia accounted for the highest number of incidence, deaths and 5-year prevalence compared to other continents [3].

Gallbladder resection is the only treatment for gallstones, and until 1986 it was performed only surgically by splitting the abdominal wall [4]. Today, laparoscopy can be performed even for surgery for acute cases of gallbladder inflammation and in patients with a hemia, abdominal ascites and pregnancy [5]. The advantages of laparoscopic cholecystectomy include shorter hospital stay, reduced postoperative pain, reduced risk of infection and incisional hernia, faster recovery and faster return to daily activities, and a better appearance and less scar than open cholecystectomy [6]. However, despite its advantages, it can cause complications in patients. Major complications of laparoscopic cholecystectomy are severe bleeding, surgical wound infection, bile leaks, bile duct injury, bowel and liver injury, pneumoperitoneum (entering the air into the peritoneal cavity for better vision during surgery), and gallstones pouring into the abdominal cavity and forming abscesses. Most of these complications are due to limited vision in this type of surgery. The incidence of these complications depends on the skill of the surgeon. Bile duct injury or stenosis, the most serious complication of laparoscopic cholecystectomy, occurs in 0.4 to 0.6% of patients. However, almost all physicians believe this is the method of choice for patients with symptomatic gallstones [7-11]. Situations such as a history of upper abdominal surgery make it difficult to perform a laparoscopic cholecystectomy. Generally, bile duct injury in laparoscopic cholecystectomy is greater than in laparotomy cholecystectomy [12].

Due to the increasing costs of the health system and limited financial resources, a low-cost strategy with the highest effectiveness is required. Currently, economic analysts in the health sector use the comprehensive term “economic evaluation” to indicate a complete set of tools that assist decision-makers in economically evaluating various technology applications [13]. Real-world decision-making is complex and involves external economic evaluation considerations such as justice and fairness, unsanitary benefits and costs, feasibility issues, etc.

Economic evaluation plays a crucial role in decision-making [14]. Economic evaluations of all procedures are widely performed worldwide to ensure that treatments are worth the cost [15]. In cost-effectiveness analysis, costs are measured in terms of money and consequences are measured and compared in terms of effectiveness units. In evaluating the cost-effectiveness of a program or procedure, a question arises as to whether their costs are fitting consequences or not [16, 17]?

Cost-effectiveness analysis measures the capability of a process to achieve its goals in terms of costs incurred. In fact, it examines the achievement of a particular product or service at the lowest possible cost. Although the cost-effectiveness of various surgery procedures has been studied in Iran, no research has been done on the cost-effectiveness of cholecystectomy surgeries. The high prevalence of
cholecystectomy in the country led us to design a study to analyze the cost-effectiveness of laparoscopic compared with laparotomy cholecystectomy among patients with a gallstone in a private hospital in Ahvaz, Iran.

Materials And Methods

Study design

This was an observational economic evaluation study to compare the cost-effectiveness of two methods of cholecystectomy (laparoscopy and laparotomy).

Study population

The study population included patients who underwent cholecystectomy in 2021 by laparoscopic and laparotomy in a private hospital in Ahvaz.

Sample size and sampling method

The sample size was determined based on the study of Lammert and Sauerbruch [18] and using the formula for comparing the means, taking into account the 95% confidence interval. To calculate the sample size, the first type of error ($z_{1-\alpha/2}$) 0.05 with power ($Z_{1-\beta}$) 80% was considered, in this formula $S_1 = 3.6$, $S_2 = 9$ and $\bar{x}_1 - \bar{x}_2 = 4$ was considered.

The formula is as follows:

$$n = \frac{(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta})^2 \times (s_1^2 + s_2^2)}{(\bar{x}_1 - \bar{x}_2)^2}$$

Patients were divided into two groups using simple random sampling. The sample comprised 62 patients undergoing laparotomy cholecystectomy and 62 undergoing laparoscopic cholecystectomy. Cost in this study was examined from the perspective of patients, and the patient's direct cost was calculated from the hospital bill. The patients were randomly selected from those who underwent cholecystectomy surgery at a private hospital from January to March 2021.

Our study was performed in two steps: Step 1) Evaluating the effectiveness based on the opinion of the surgeons (n=5) at the hospital encompassed the length of hospital stay, return to work, pain, surgery time and infection after surgery. In order to ask questions about time lost to return to normal activity or work, patients were followed up until one month after treatment. Also, to calculate the total effectiveness of surgeries, five surgeons were asked to weigh the effectiveness indices. The weight of each index was calculated from the total scores (ranging from 0 to 100). Patients were followed up until one month after treatment.

Step 2) costs such as the surgeon, operating room supplies assistant, surgeon, anesthesia, and hoteling were extracted from the patient's bill. All costs were converted to US dollars based on the Purchasing Power Parity (PPP) in 2021 [19].

Inclusion and exclusion criteria

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

Data collection tools

Data collection tools consisted of three parts. The first part consisted of questions related to demographic information (e.g. age, gender, marital status, education status, income). The second part consisted of questions related to costs (e.g. surgeon costs, operating room supplies, surgeon assistance, anesthesia and hoteling). The third part was related to effectiveness components (e.g. pain, days of hospitalization, duration of surgery, days of return to work and infection) in which questions related to effectiveness were obtained through interviews. At the interview, we asked patients to fill out an informed consent form and give us information such as an address, contact number, and needed demographic information. Moreover, information on costs, length of hospital stay, time to return to work, pain (using the VAS questionnaire) and operation time were obtained from the patient record. For the infection index, recurrence within 48 hours after discharge and having symptoms of infection (such as fever, etc.) was considered as an indicator, according to the doctor's diagnosis and registration in hospital records.

Statistical analysis
We used SPSS 22 and STATA 14.2 for data analysis. Frequency distribution tables and related graphs, mean, standard deviation, MD, Cohen's d, independent t-test and ANOVA, were used to compare the costs and effectiveness of two surgical methods. Tornado diagrams and one-way sensitivity analysis were drawn for economic evaluation analyses using Tree Age software. SPSS 22 software was used for data analysis. Frequency distribution tables and related graphs (for qualitative data) and mean and standard deviation (SD) (for quantitative data) were used to describe the data and independent t-test. ANOVA was used to compare the mean. The incremental cost-effectiveness ratio (ICER) was calculated using $\Delta$ COST / $\Delta$ EFFECTIVENESS.

Ethical considerations

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 study, researchers were introduced to the hospital by the Vice-Chancellor for Research and Postgraduate Studies. Prior to the study, the objective of the study was explained to all participants and written informed consent was obtained. Participants were assured that all information supplied would be anonymous and kept confidentially. Participation was voluntary, and participants could withdraw at any time without any consequences. The researchers were committed to following the principles of ethics in research in data collection, analysis and final report. All methods were carried out in accordance with relevant guidelines and regulations.

Results

The demographic characteristics of participants are shown in Table 1. The mean age of patients undergoing Laparoscopy and Laparotomy was 34.74 (SD = 1.38) and 35.41 (SD = 1.37) years, respectively. 51% of participants had less than 105 US$ monthly income. The income level of 35% of participants ranged from 106 to 210 US$, and only 15% had an income level of more than 211 US$.

Table 1: Demographic characteristics of participants

<table>
<thead>
<tr>
<th>Factor</th>
<th>Level</th>
<th>Laparoscopy (N=62)</th>
<th>Laparotomy (N=62)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Male</td>
<td>28 (45%)</td>
<td>30 (48%)</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>34 (55%)</td>
<td>32 (52%)</td>
<td></td>
</tr>
<tr>
<td>Age, median (IQR)</td>
<td>34.0 (26.0, 42.0)</td>
<td>34.0 (28.0, 42.0)</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>Marital Status</td>
<td>Married</td>
<td>40 (65%)</td>
<td>43 (69%)</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>Single</td>
<td>22 (35%)</td>
<td>19 (31%)</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>Up to high school</td>
<td>36 (58%)</td>
<td>30 (48%)</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>College education</td>
<td>26 (42%)</td>
<td>32 (52%)</td>
<td></td>
</tr>
</tbody>
</table>

The mean costs of laparoscopy and laparotomy are represented in Table 2.
Table 2. Mean costs of Laparoscopy and Laparotomy

<table>
<thead>
<tr>
<th>Costs</th>
<th>Type of Treatment</th>
<th>Obs.</th>
<th>Mean (US $)</th>
<th>SD</th>
<th>Std. Err.</th>
<th>Mean 95% CI</th>
<th>t</th>
<th>P-value</th>
<th>Mean Diff. (Laparoscopy – Laparotomy)</th>
<th>MD 95% CI</th>
<th>SMD (Cohen’s d) SMD 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgeon</td>
<td>Laparoscopy</td>
<td>62</td>
<td>226.65</td>
<td>32.77</td>
<td>4.16</td>
<td>218.33 to 234.97</td>
<td>3.67</td>
<td>&lt; 0.01</td>
<td>28.03</td>
<td>12.90</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>Laparotomy</td>
<td>62</td>
<td>198.62</td>
<td>50.50</td>
<td>6.41</td>
<td>185.80 to 211.44</td>
<td>45.03</td>
<td>&lt; 0.01</td>
<td>44.50</td>
<td>42.54</td>
<td>8.09</td>
</tr>
<tr>
<td>Essential Equipment</td>
<td>Laparoscopy</td>
<td>62</td>
<td>82.82</td>
<td>4.72</td>
<td>0.60</td>
<td>81.62 to 84.02</td>
<td>-13.88</td>
<td>&lt; 0.01</td>
<td>-13.47</td>
<td>-15.40</td>
<td>-2.50</td>
</tr>
<tr>
<td></td>
<td>Laparotomy</td>
<td>62</td>
<td>38.32</td>
<td>6.18</td>
<td>0.79</td>
<td>36.75 to 39.89</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assistant Surgeon</td>
<td>Laparoscopy</td>
<td>62</td>
<td>47.64</td>
<td>4.79</td>
<td>0.61</td>
<td>46.42 to 48.86</td>
<td>-7.05</td>
<td>&lt; 0.01</td>
<td>-38.83</td>
<td>-49.72</td>
<td>-1.65</td>
</tr>
<tr>
<td></td>
<td>Laparotomy</td>
<td>62</td>
<td>61.11</td>
<td>5.95</td>
<td>0.76</td>
<td>59.60 to 62.63</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anaesthesia</td>
<td>Laparoscopy</td>
<td>62</td>
<td>30.22</td>
<td>3.78</td>
<td>0.48</td>
<td>29.26 to 31.18</td>
<td>3.00</td>
<td>&lt; 0.01</td>
<td>1.90</td>
<td>0.65</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>Laparotomy</td>
<td>62</td>
<td>28.31</td>
<td>3.25</td>
<td>0.41</td>
<td>27.48 to 29.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hoteling</td>
<td>Laparoscopy</td>
<td>62</td>
<td>94.28</td>
<td>30.10</td>
<td>3.82</td>
<td>86.64 to 101.93</td>
<td>-7.05</td>
<td>&lt; 0.01</td>
<td>-38.83</td>
<td>-49.72</td>
<td>-1.27</td>
</tr>
<tr>
<td></td>
<td>Laparotomy</td>
<td>62</td>
<td>133.12</td>
<td>31.18</td>
<td>3.96</td>
<td>125.20 to 141.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total costs (except hoteling)</td>
<td>Laparoscopy</td>
<td>62</td>
<td>387.33</td>
<td>33.22</td>
<td>4.22</td>
<td>370.89 to 395.77</td>
<td>7.91</td>
<td>&lt; 0.01</td>
<td>60.96</td>
<td>45.71</td>
<td>1.42</td>
</tr>
<tr>
<td></td>
<td>Laparotomy</td>
<td>62</td>
<td>326.36</td>
<td>50.76</td>
<td>6.45</td>
<td>313.47 to 339.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Laparoscopy</td>
<td>62</td>
<td>481.61</td>
<td>49.33</td>
<td>6.26</td>
<td>469.09 to 494.14</td>
<td>2.11</td>
<td>0.03</td>
<td>22.13</td>
<td>1.40</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Laparotomy</td>
<td>62</td>
<td>459.48</td>
<td>66.10</td>
<td>8.39</td>
<td>442.69 to 476.27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

According to the independent t-test, a significant difference was observed between costs and treatment procedures. Moreover, the results of the calculated SMD (Cohen’s d) showed a significant difference between the two surgical methods. The mean difference for the laparoscopy procedure's total costs was higher than the laparotomy procedure. SMD for total costs was estimated at 0.38 (95% CI: 0.02 to 0.73), indicating a weak MD effect size. Given that the mean LoS for laparoscopy patients was lower than that of laparotomy patients 2.69 (SD= 0.86 and 95% CI: 2.47 to 2.91) VS 3.91 (SD=0.92 and 95% CI: 3.68 to 4.15)), we did not consider hoteling costs and compared only surgical procedure costs. Consequently, the mean difference increased to more than 60$. Cohen’s d results showed a very large size SMD for surgery procedure 1.42 (95% CI: 1.02 to 1.81).
Table 3. Mean scores of effectiveness in different dimensions by type of procedure

<table>
<thead>
<tr>
<th>Effectiveness</th>
<th>Type of treatment</th>
<th>Obs.</th>
<th>Mean</th>
<th>SD</th>
<th>Std. Err.</th>
<th>Mean 95% CI</th>
<th>t-Value</th>
<th>P-Value</th>
<th>Mean Diff. (Laparoscopy - Laparotomy)</th>
<th>MD 95% CI</th>
<th>SMD (Cohen's d)</th>
<th>SMD 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>Laparoscopy</td>
<td>62</td>
<td>23.47</td>
<td>6.15</td>
<td>0.78</td>
<td>21.91 to 25.03</td>
<td>5.40</td>
<td>&lt; 0.001</td>
<td>7.25</td>
<td>4.60 to 9.92</td>
<td>0.97</td>
<td>0.60 to 1.34</td>
</tr>
<tr>
<td></td>
<td>Laparotomy</td>
<td>62</td>
<td>16.21</td>
<td>8.61</td>
<td>1.09</td>
<td>14.02 to 18.40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of stay</td>
<td>Laparoscopy</td>
<td>62</td>
<td>8.50</td>
<td>1.61</td>
<td>0.20</td>
<td>8.09 to 8.91</td>
<td>8.60</td>
<td>&lt; 0.001</td>
<td>2.27</td>
<td>1.75 to 2.80</td>
<td>1.54</td>
<td>1.14 to 1.94</td>
</tr>
<tr>
<td></td>
<td>Laparotomy</td>
<td>62</td>
<td>6.22</td>
<td>1.32</td>
<td>0.19</td>
<td>5.89 to 6.56</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days for back to work</td>
<td>Laparoscopy</td>
<td>62</td>
<td>13.39</td>
<td>3.81</td>
<td>0.48</td>
<td>12.42 to 14.36</td>
<td>5.06</td>
<td>&lt; 0.001</td>
<td>3.71</td>
<td>2.26 to 5.16</td>
<td>0.91</td>
<td>0.54 to 1.28</td>
</tr>
<tr>
<td></td>
<td>Laparotomy</td>
<td>62</td>
<td>9.68</td>
<td>4.33</td>
<td>0.55</td>
<td>8.58 to 10.78</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of surgery (10 minute)</td>
<td>Laparoscopy</td>
<td>62</td>
<td>7.48</td>
<td>1.81</td>
<td>0.23</td>
<td>7.02 to 7.94</td>
<td>0.98</td>
<td>0.33</td>
<td>0.29</td>
<td>-0.29 to 0.88</td>
<td>0.18</td>
<td>-0.18 to 0.53</td>
</tr>
<tr>
<td></td>
<td>Laparotomy</td>
<td>62</td>
<td>7.19</td>
<td>1.47</td>
<td>0.19</td>
<td>6.62 to 7.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infection</td>
<td>Laparoscopy</td>
<td>62</td>
<td>29.30</td>
<td>5.34</td>
<td>0.68</td>
<td>27.68 to 30.39</td>
<td>1.16</td>
<td>0.25</td>
<td>1.45</td>
<td>-1.02 to 3.92</td>
<td>0.21</td>
<td>-0.14 to 0.56</td>
</tr>
<tr>
<td></td>
<td>Laparotomy</td>
<td>62</td>
<td>27.58</td>
<td>8.24</td>
<td>1.05</td>
<td>25.49 to 29.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total effectiveness</td>
<td>Laparoscopy</td>
<td>62</td>
<td>83.44</td>
<td>11.34</td>
<td>1.44</td>
<td>80.56 to 86.32</td>
<td>6.69</td>
<td>&lt; 0.001</td>
<td>15.05</td>
<td>10.59 to 19.50</td>
<td>1.2</td>
<td>0.81 to 1.58</td>
</tr>
<tr>
<td></td>
<td>Laparotomy</td>
<td>62</td>
<td>68.39</td>
<td>13.62</td>
<td>1.72</td>
<td>64.94 to 71.85</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cohen’s d demonstrated a very large size SMD for effectiveness between laparoscopy and laparotomy in “pain”, “days for returning to work”, and “Los” subscales. While the duration of surgery and infection subscales were not significantly different, their SMD was not considerable. The mean length of stay (LoS) was 2.6 (SD=0.9) for patients who underwent laparoscopy and 3.7 (SD=0.9) days for patients who underwent Laparotomy. This difference was statistically significant (p<0.001), according to the Two-Sample t-test. LoS median (IQR) for patients undergoing laparoscopy was 2.0 (2.0, 3.0), while for those undergoing laparotomy was found to be 4.0 (3.0, 5.0).

Mean days for returning to work among patients who underwent laparoscopy was estimated at 6.0 (SD=1.7), while that for those undergoing laparotomy was estimated at 7.6 (SD=1.8), and this difference was statistically significant (p<0.001). The median (IQR) time to return to work (days) following laparoscopy and laparotomy was 6.0 (5.0, 7.0) and 8.0 (6.0, 9.0), respectively.

Table 4 shows the incremental cost-effectiveness ratio (ICER).
A unit of effectiveness in laparoscopy costs $1.47 less than a laparotomy. But if we calculate the cost-effectiveness of the two methods without considering the cost of hoteling, this number increased to 4.05 and decreased the cost-effectiveness of the laparoscopic method.

Since the infection index was scored by the five surgeons who determined the surgical index as the most important index (along with pain) (30 out of 100), a one-way sensitivity analysis was carried out based on the infection index (Fig. 1). The figure indicates the extent of ICER changes based on changes in the infection during the laparoscopy. When the infection was less than 97.76, the laparotomy had a probability of being cost-effective. But when the figure was higher than 97.76, laparoscopy had a higher probability of being cost-effective. In this diagram, when ICER is negative, indicating that the procedure is not cost-effective, the procedure is cost-effective if ICER is positive.

The sensitivity analysis results are shown in the Tornado diagram (Fig. 2). 12 variables were ordered from top to bottom according to their maximum impact on ICER. The surgeon's cost in laparoscopy had the greatest impact on ICER. This has meant that if the surgeon's cost for the laparoscopy were considered in the minimum and maximum range, the ICER would decrease from $350.000 to approximately $-125.000. But this change did not affect the cost-effectiveness outcome. Therefore, by changing this variable, the laparoscopy procedures are still cost-effective. But by changing the variables of surgeon cost, hoteling cost, equipment cost and surgeon's assistant cost in laparotomy, and hoteling cost y, equipment cost anaesthesia cost in laparotomy at their minimum and maximum range, laparotomy had a high probability of being cost-effective. Moreover, the two variables of days of returning to work in laparoscopy and laparotomy at some intervals led to considerable changes in ICER and cost-effectiveness outcome, which is shown as an infinite sign in the diagram.

### Discussion

This study aimed to compare the cost-effectiveness of laparotomy cholecystectomy versus laparoscopy. Our results showed that the mean cost in patients undergoing laparoscopy was significantly higher than those undergoing laparotomy. Although the cost of laparoscopy was higher than laparotomy, the effectiveness of this procedure in all criteria was higher than that of laparotomy. Finally, laparoscopic cholecystectomy was found to be more cost-effective than laparotomy cholecystectomy. Therefore, the decision to choose the type of surgery should be based on the mutual opinion of the physician and the patient and which method is preferable. The results obtained in our study are in line with others that have reported an economic advantage when using a laparoscopic technique for other diseases [20-25].

In this study, we found that in terms of effectiveness, length of hospital stay and time to return to work in patients undergoing laparoscopic surgery were significantly shorter than those undergoing laparotomy. Moreover, patients undergoing laparoscopic surgery reported lower pain than those undergoing laparotomy. This difference can be attributed to the smaller surgical incision in the laparoscopic procedure. In addition, due to the specialization of laparoscopic procedure, the use of specialized surgical instruments and the need to pass the required courses, the cost of the surgeon and materials in this procedure is higher than the laparotomy procedure. However, this cost is partially offset by the high cost of hoteling among patients undergoing laparotomy, ultimately making the laparoscopic procedure more cost-effective. Similar results were reported in previous studies that compared these two methods for other diseases. In all studies, the length of stay and time to free activity was shorter in patients who underwent laparoscopic than those who underwent laparotomy [20-22, 24, 26]. Compared with traditional laparotomy, laparoscopic surgery is more accepted, and it is associated with the relative advantages of smaller wounds, reduced pain, shorter length of hospital stay, shorter operation time, 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, and then changed each of these variables it had no effect on the total cost-effectiveness. Furthermore, according to the tornado diagram, although the surgeon’s cost had the highest role in the total cost, removing each of the cost indicators (e.g. surgeon costs, surgeon assistance, operating room consumables, anesthesia and hoteling) did not affect the total cost-effectiveness.

Our study has some limitations. First, indirect costs were not estimated in this study. Second, due to the short follow-up period, it was impossible to consider long-term surgical complications such as surgical site hernia and adhesions. Third, although the results of this study are

<p>| Table 4: Incremental cost-effectiveness ratio (ICER) with and without hoteling cost |
|--------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>variables</th>
<th>Type of treatment</th>
<th>Total cost (US$)</th>
<th>Effectiveness</th>
<th>Cost-Effectiveness</th>
<th>Effectiveness</th>
<th>ICER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost-effectiveness excluding</td>
<td>Laparoscopy</td>
<td>387.33</td>
<td>83.44</td>
<td>4.64</td>
<td>60.96</td>
<td>15.05</td>
</tr>
<tr>
<td>Hoteling costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cost-effectiveness</td>
<td>Laparoscopy</td>
<td>481.61</td>
<td>83.44</td>
<td>5.77</td>
<td>22.13</td>
<td>15.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Discussion**

This study aimed to compare the cost-effectiveness of laparotomy cholecystectomy versus laparoscopy. Our results showed that the mean cost in patients undergoing laparoscopy was significantly higher than those undergoing laparotomy. Although the cost of laparoscopy was higher than laparotomy, the effectiveness of this procedure in all criteria was higher than that of laparotomy. Finally, laparoscopic cholecystectomy was found to be more cost-effective than laparotomy cholecystectomy. Therefore, the decision to choose the type of surgery should be based on the mutual opinion of the physician and the patient and which method is preferable. The results obtained in our study are in line with others that have reported an economic advantage when using a laparoscopic technique for other diseases [20-25].

In this study, we found that in terms of effectiveness, length of hospital stay and time to return to work in patients undergoing laparoscopic surgery were significantly shorter than those undergoing laparotomy. Moreover, patients undergoing laparoscopic surgery reported lower pain than those undergoing laparotomy. This difference can be attributed to the smaller surgical incision in the laparoscopic procedure. In addition, due to the specialization of laparoscopic procedure, the use of specialized surgical instruments and the need to pass the required courses, the cost of the surgeon and materials in this procedure is higher than the laparotomy procedure. However, this cost is partially offset by the high cost of hoteling among patients undergoing laparotomy, ultimately making the laparoscopic procedure more cost-effective. Similar results were reported in previous studies that compared these two methods for other diseases. In all studies, the length of stay and time to free activity was shorter in patients who underwent laparoscopic than those who underwent laparotomy [20-22, 24, 26]. Compared with traditional laparotomy, laparoscopic surgery is more accepted, and it is associated with the relative advantages of smaller wounds, reduced pain, shorter length of hospital stay, shorter operation time, 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, and then changed each of these variables it had no effect on the total cost-effectiveness. Furthermore, according to the tornado diagram, although the surgeon’s cost had the highest role in the total cost, removing each of the cost indicators (e.g. surgeon costs, surgeon assistance, operating room consumables, anesthesia and hoteling) did not affect the total cost-effectiveness.

Our study has some limitations. First, indirect costs were not estimated in this study. Second, due to the short follow-up period, it was impossible to consider long-term surgical complications such as surgical site hernia and adhesions. Third, although the results of this study are
similar to the results of many other surgeries performed by laparotomy and laparoscopy, they can't be generalized to other surgeries due to differences in the nature of surgery. Finally, the generalization of our results is limited to private hospitals.

**Conclusion**

Although laparoscopic cholecystectomy was more expensive than laparotomy cholecystectomy, it was generally more cost-effective. The results of this research may help Iran's health system policymakers and managers in order to extend laparoscopic cholecystectomy in more hospitals.

**Declarations**

**Ethical approval and consent to participate**

This study was approved by the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences (Reference No: IR.AJUMS.REC.1399.791). Prior to the study, the objectives of the study was explained to all participants and written informed consent was obtained. Participants were assured that all information supplied would be anonymous and kept confidentially. We followed the ethical protocols in accordance with the relevant guidelines and regulations.

**Consent for publication**

Not applicable.

**Availability of data and materials**

The data set used in the current study is available from the corresponding author on reasonable request.

**Competing interests**

The authors declare no conflicts of interest in all of research steps.

**Funding**

This study was supported by Ahvaz Jundishapur University of Medical Sciences (Grant No: U-99314).

**Authors' contributions**

FF, NF and HA contributed to developing study concept and design. HA collected data. FF and MH analyzed data. All authors contributed to writing the manuscript. All authors have read and approved the final manuscript.

**Acknowledgements**

This manuscript is part of a project for Hamed Abdollahi's Master degree (MSc.) in Health Services Management. The authors express their gratitude to the officials of the Vice Chancellor for Research of Ahvaz Jundishapur University of Medical Sciences and the officials and staff of Aria hospital in Ahvaz. Finally, the authors specially appreciate Dr. Habib Jalilian, the faculty member of the School of Health, Ahvaz Jundishapur University of Medical Sciences.

**References**


Figures
Figure 1

One-way sensitivity analysis chart based on changes in infection variables in laparoscopic strategy

Figure 2

Results of definitive sensitivity analysis in a tornado diagram