Asian Journal of Surgery (2019) 42, 543–550

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.e-asianjournalsurgery.com

ORIGINAL ARTICLE

Is robotic hepatectomy cost-effective? In view of patient-reported outcomes

Chao-Ying Wu [a,1], Po-Da Chen [b,1], Wei-Han Chou [c], Jin-Tung Liang [b], Chiun-Sheng Huang [b], Yao-Ming Wu [b,*]

[a] Department of Surgery, National Taiwan University Hospital, Yunlin Branch, Taiwan
[b] Department of Surgery, National Taiwan University Hospital, Taiwan
[c] Department of Anesthesia, National Taiwan University Hospital, Taiwan

Received 13 November 2018; received in revised form 5 December 2018; accepted 20 December 2018
Available online 29 January 2019

KEYWORDS
Robotic hepatectomy;
Patient-reported outcome;
Quality of life;
Cost-effectiveness

Summary *Background:* Robotic hepatectomy has been accepted as an alternative for patients needing surgery. However, few reports addressed the patient-reported outcomes and long-term quality of life (QoL) of patients having undergone robotic liver surgery.
Methods: This study presented the QoL and cost-effectiveness associated with robotic and open hepatectomy by performing a comparative survey using two standardized questionnaires (Short Form-36 and Gastrointestinal Quality of Life Index).
Results: One hundred patients completed the study. The robotic group tended to experienced longer operation time but shorter length of hospital stay compared to open group. Moreover, the robotic group had faster return to daily activities, less need of patient-controlled anesthesia, and less wound-related complaints in long-term follow-up. The robotic group incurred higher peri-operative expenses; however, the cost of inpatient care was lower.
Conclusions: Our study suggested that robotic hepatectomy provided good post-operative QoL and recovery of daily activity. However, efforts for lowering the financial burden of medical care by reducing the cost of robotic surgery is necessary for further application.

* Corresponding author. Department of Surgery, National Taiwan University Hospital, No 7, Chung-Shan South Road, Taipei, 100, Taiwan. Fax: +886 2 33223476.
E-mail address: wyaoming@gmail.com (Y.-M. Wu).
[1] The first two authors contributed equally to this study.

https://doi.org/10.1016/j.asjsur.2018.12.010

1. Introduction

Minimally invasive surgery for liver surgery has improved and currently shown to have comparable surgical outcomes as well as oncological results compared to those of standard open hepatectomy.[1–3] However, the development of the new techniques for hepatectomy is slow as a careful parenchymal dissection is necessary due to the complex vascular anatomy. As the minimally invasive approaches have advanced, the robotic platform now allows stable vision with flexible instruments, and it is suggested to provide benefits for patients in need of major hepatectomy.[4,5] Considering our learning curve in the MIS hepatectomy,[6] we believe the robotic hepatectomy can be considered as a new surgical technique, contributing not only improved views and flexible robotic arms, but applications to liver lesions with similar indications as the open approach. Moreover, the robotic hepatectomy is associated with the high cost of using the da Vinci system; thus, there are needs to compare and analyze the QoL outcomes and cost-effectiveness of the robotic and open hepatectomy in detail.

With the development of modern medicine, surgery is intended not only to cure, but also to improve quality of life (QoL). Robotic surgery has been considered cost-effective due to enhanced post-operative QoL and faster recovery in urological, gynecological, cardiac, and general surgery.[7–11] Our previous studies also suggested that robotic hepatectomy provides a faster recovery regarding the post-operative course and return to daily life, despite it being a major and complex procedure.[12,13] However, whether robotic surgery of the liver improves QoL and cost-effectiveness remains a debate. No standardized questionnaire was applied for assessing QoL after hepatectomy as part of the methodology in the limited studies performed, and most studies only provided data with few and subjective responses of the patients. Herein, the study was conducted to present the patient-reported outcomes with post-operative QoL and cost-effectiveness regarding robotic hepatectomy.

2. Methods

All patients who underwent robotic and open hepatectomy between August 2012 and February 2016 by our surgical team were invited to join the study, except those with daily performance worse than Eastern Cooperative Oncology Group (ECOG) Performance State 1 before the operation,[14] or malignancy of organs other than the liver and simultaneous resection of organs other than the liver and gallbladder. Because most patients had regular follow-up at an outpatient clinic every 3 months, this cross-sectional study using standardized questionnaires was performed between March 2016 and May 2016 during the outpatient clinic visit. All participants signed informed consent forms prior to the questionnaire survey, and the study was approved by the review board of our institute. For patients underwent open hepatectomy, a 15–20 cm incision was performed for subcostal laparotomy with cephalic extension or reverse-T laparotomy; robotic hepatectomy used 4 or 5 trocar with a 3–5 cm laparotomy for specimen removal as illustrated in our previous report.[5]

2.1. Peri-operative outcomes

Peri-operative outcomes of robotic and open hepatectomy, including demographic data, pre-operative assessments, surgery-related perioperative details, pathological results and short-term outcomes, were analyzed. The Brisbane 2000 Terminology of Liver Anatomy and Resections was applied for nomenclature of hepatic resection in this study.[15]

2.2. Quality of life (QoL)

The most common wound-related complaint after surgery is pain. To assess this aspect of QoL, subjective responses on the post-operative visual analogue scale (VAS) were analyzed along with objective responses obtained from the need for patient-controlled anesthesia (PCA). Moreover, the time to return to daily activities and long-term subjective feelings of the patient regarding the T were analyzed.

2.3. Standardized questionnaires (Short Form-36 [SF-36] and Gastrointestinal Quality of Life Index [GIQLI])

Formal permission to use the Chinese version of the SF-36v2® Health Survey was obtained for this study.[16] Thirty-six questions were used to assess QoL on eight health concepts: general health, physical functioning, role-physical, body pain, vitality, social functioning, role-emotional, and mental health.[17] The final scores of each health concept were analyzed after importing the original data into the software. A higher score denotes a higher quality of each domain.

The GIQLI is also composed of 36 items, of which are reviewed in 5 main domains: physical states, emotional states, social functioning, gastrointestinal symptoms, and the effect of medical treatment.[18,19] Scores for each item range from 0 to 4, which are summarized to produce a total score between 0 and 144. A higher score indicates a better QoL.

The questionnaire survey was collected through personal interview in an isolated room at the outpatient clinic. Each interview required 25–40 min to complete.

2.4. Cost analysis

The total cost of hepatectomy in this study was analyzed by two main aspects: peri-operative cost and inpatient care cost. The peri-operative cost was divided into operating room and anesthesia costs. All other medical payments, including inpatient services, pain control, laboratory examination, radiology examination, pharmacy, treatment of complications (if present), and room and board were included in the cost of inpatient care. The performances of robotic and open hepatectomy and post-operative care were based on the same surgical principle by a single surgical team. Major differences between the two procedures were as follows. Open hepatectomy used the Cavitron Ultrasonic Surgical Aspirator while the Harmonic scalpel (Endo-Surgery, Cincinnati, Ohio, USA) was applied with the

da Vinci® Surgical System for robotic hepatectomy. Additionally, the cost of robotic hepatectomy did not include the purchase price of the da Vinci® Surgical System and the yearly maintenance fee.

2.5. Statistics analysis

Patients were subdivided into four different subgroups according to post-operative period: post-operative 3 months, 6 months, 12 months, and 24 months. In this study, continuous data were presented as mean ± SD. Either an independent *t*-test or a χ^2 test was used, where appropriate, to compare group variables. For all statistical evaluations, a value of two-sided *p* less than 0.05 was considered statistically significant. All statistical analyses were carried out with Statistical Package for Social Sciences (SPSS)® version 19.0 (IBM Corporation, Armonk, NY, USA).

3. Results

A total of 163 patients with ECOG 0 performance before the operation underwent robotic or open hepatectomy without simultaneous surgery between August 2012 and February 2016. All 163 patients were invited to join the study. Among them, 50 patients who underwent robotic hepatectomy and 50 who underwent open hepatectomy completed the questionnaire survey.

3.1. Peri-operative outcomes

Treatment for malignancy was the main indication for hepatectomy among these patients as illustrated in Table 1. The robotic group shared similar demographic characteristics with the open group, except for more benign disease (18/50 vs. 6/50) and smaller tumor size (4.2 vs. 6.0 cm). There were no significant differences between the two groups regarding intra-operative blood loss, transfusion requirements, and surgery-related complications. The robotic group experienced longer operation time (354 vs 246 min, $p < 0.001$), but shorter length of post-operative hospital stay (7.5 vs 11.3 days, $p < 0.001$).

3.2. Quality of life

Patients used patient-controlled anesthesia (PCA) at will; the penetration rate of PCA for robotic and open hepatectomy was 70% and 88%, respectively. Patients who underwent robotic hepatectomy tended to need less PCA after the operation as illustrated in Fig. 1. Use on the operative day (15.3 mg vs 8.6 mg of morphine, $p < 0.001$) and the total dosage of PCA (42.5 mg vs 63.9 mg of morphine, $p = 0.029$) were significantly lower in robotic groups. Despite the lower PCA dosage, the robotic group experienced similar pain levels based on subjective VAS score. However, the pain score was significantly lower in the robotic group after discontinuing PCA at post-operative 1 week (Table 2). The difference in QoL regarding pain between the two groups persisted for one month. Although the two groups reported similar responses regarding wound cosmetics, the robotic group reported less wound numbness ($p = 0.014$), while complaints associated with large wounds were observed more in the open group.

The analysis of objective questionnaire evaluation (SF-36 and GIQLI) is shown in Table 3. In view of the eight health concepts presented in SF-36, the robotic group provided significantly better physical results at post-operative 3 months and 6 months, and better mental results at post-operative 6 months than the open group. Moreover, in consideration of the 5 main domains presented in GIQLI, the robotic group was reported to have better physical and emotional states at post-operative 6 months, and better

Table 1 Peri-operative outcomes of robotic and open hepatectomy.

	Robotic Group (n = 50)	Open Group (n = 50)	*p* value
Age (yrs)	53.4 ± 15.7	58.7 ± 11.3	0.05
Sex (M:F)	34:16	33:17	1
BMI	24.2 ± 3.4	24.8 ± 3.7	0.35
HBsAg positive	52%	50%	0.66
HCV positive	8%	14%	0.51
Cirrhosis	32%	50%	0.10
Procedures			0.21
Right hepatectomy	14	21	
Left hepatectomy	12	4	
Trisegmentectomy	2	11	
Minor hepatectomy	22	14	
Operation time (min)	354.0 ± 160.8	246.0 ± 79.3	<0.001*
Blood loss (mL)	233.0 ± 398.7	369.2 ± 413.2	0.10
Blood transfusion rate	6%	10%	0.72
Post-operative hospital stay (days)	7.5 ± 3.5	11.3 ± 5.2	<0.001*
Peri-operative deaths	0	0	—
Peri-operative complications	6%	14%	0.32

Values are in mean ± standard deviation * Statistically significant, $p < 0.05$; AST, aspartate aminotransferase; ALT, alanine aminotransferase; HBsAg, hepatitis B virus; HCV, hepatitis C virus.

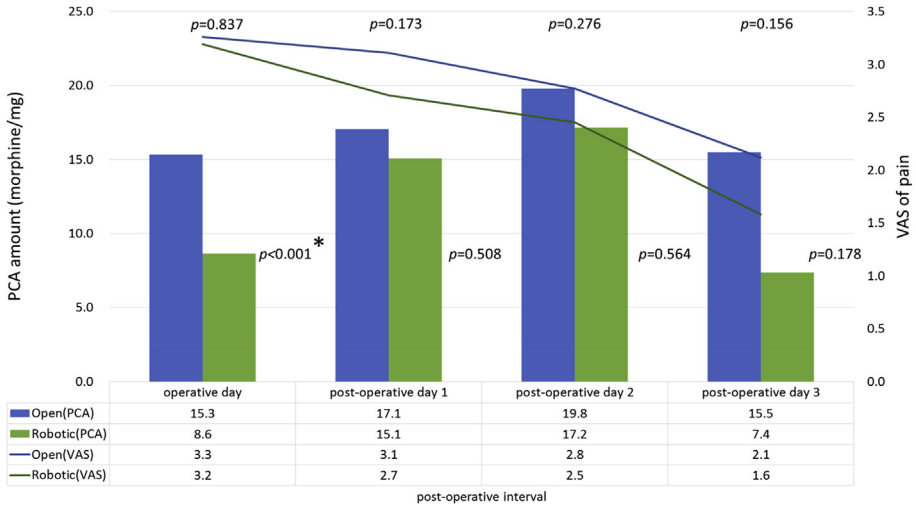


Figure 1 Comparison of short-term pain between the robotic and open groups. The robotic group needed less PCA after surgery (with statistical significance on the surgery day) while this group reported similar subjective VAS for pain compared to the open group. VAS, visual analog scale; PCA, patient-controlled anesthesia.

social functioning and physical states at post-operative 18 months than the open group.

In addition, the robotic group reported a shorter period before returning to daily activity than the open group (Fig. 2). The analysis revealed significance differences in starting ambulation without assistance (3.6 days vs 6.8 days, $p < 0.001$), toileting without assistance (4.2 days vs 6.6 days, $p = 0.004$), self-care independence (9.6 days vs 19.6 days, $p = 0.001$), jogging (53.0 days vs 101.7 days, $p = 0.036$), and sexual activity (74.0 days vs 108.8 days, $p = 0.043$).

3.3. Cost analysis

Robotic hepatectomy is associated with a higher total cost compared to open hepatectomy (Table 4). When divided by peri-operative and inpatient-care costs, the higher peri-operative cost in the robotic group was consistent with the costs from the use of the robotic system and higher anesthesia fee due to longer operation time. However, patients who underwent robotic hepatectomy had lower cost of inpatient care, including less room fees due to shorter hospital stay, as well as associated pharmacy and laboratory costs.

Table 2 Subjective wound-related responses of robotic and open hepatectomy.

	Robotic Group (n = 50)	Open Group (n = 50)	p value
Long-term wound pain (mean VAS)			
POD 1 week	2.4	3.4	0.046*
POD 1 month	0.6	1.3	0.02*
POD 3 month	0.1	0.4	0.07
POD 6 month	0.1	0.3	0.07
Wound numbness (POD 3 month)			0.014*
No or Mild	49	39	
Moderate or Severe	1	3	
Wound cosmetics (POD 3 months)			0.16
Poor	0	1	
Fair or Good	27	36	
Excellent	23	13	

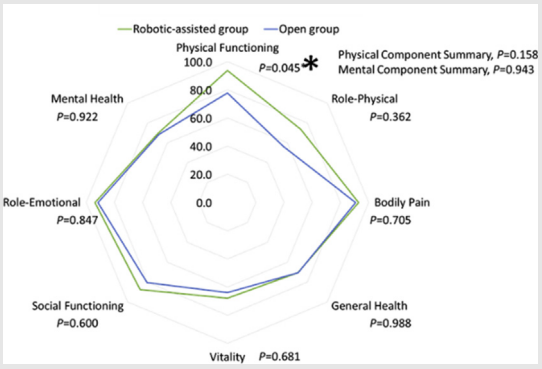
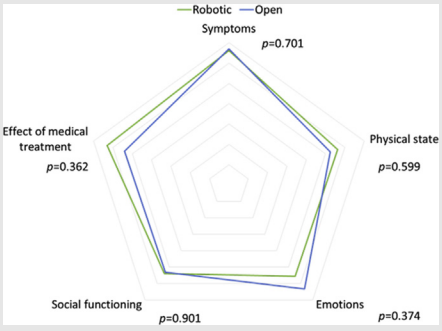
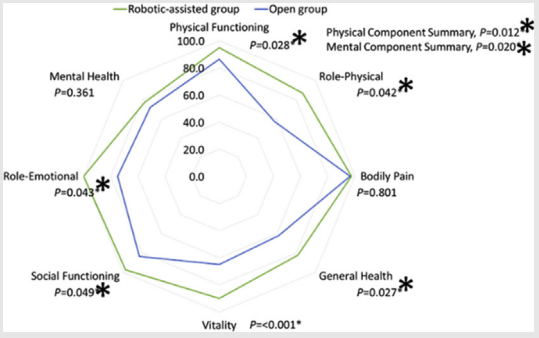
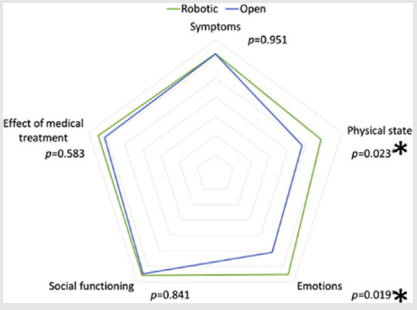
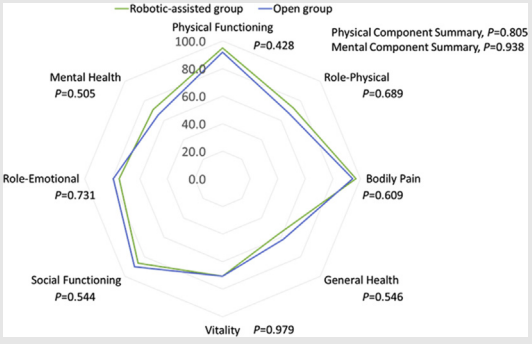
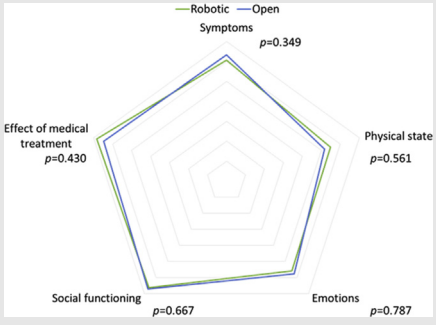
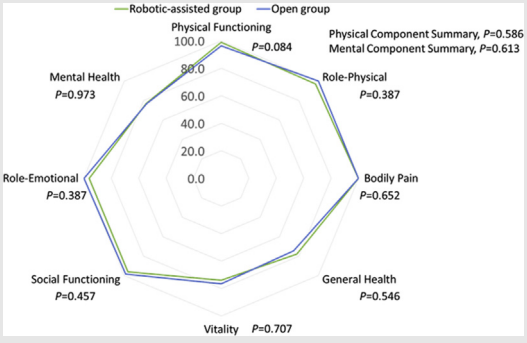
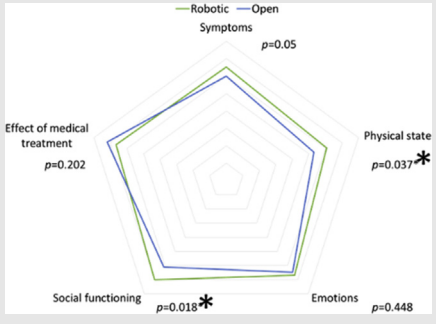
*Statistically significant $p < 0.05$ VAS, visual analogue score; POD, post-operative day.

4. Discussion

With comparable safety and feasibility, robotic hepatectomy has been introduced as an alternative to the open approach for liver surgery.[12,20] To the best of our knowledge, our study is the first to provide an objective analysis of responses to standardized QoL questionnaires.[10,11] Few reports have addressed the cost-effectiveness between laparoscopic and open hepatectomy, however, the robotic hepatectomy should be considered as a new surgical technique for the advanced applications to liver lesions with similar indications as the open procedure. Moreover, the high cost of the da Vinci system remained a concern for further adoption of the robotic hepatectomy. The cost-effectiveness analysis of the robotic and open hepatectomy is needed in evaluating post-operative QoL and patient-reported outcomes.

Pain is one of the most direct and important indicators for QoL after surgery. Our data suggest that patients who underwent robotic hepatectomy experience less post-operative pain than the open approach. Although subjective VAS scores for pain were similar between the robotic and open groups, a benefit of the robotic approach was highlighted by less frequent use of PCA, which is a more objective measurement. It is surprising that the two groups reported similar responses regarding wound cosmetics. The focus of better prognosis in malignancy might reduce the desire for improved wound cosmetics. However, pain from the large wounds associated with open hepatectomy persisted for one month after surgery, in which the difference

Table 3 SF-36 and GILQI analysis for QoL of the robotic and open groups.

Post-operative months	Short Form 36	Gastrointestinal Quality of Life Index
3 months		
6 months		
12 months		
More than 18 moths		

*Statistically significant, $p < 0.05$.

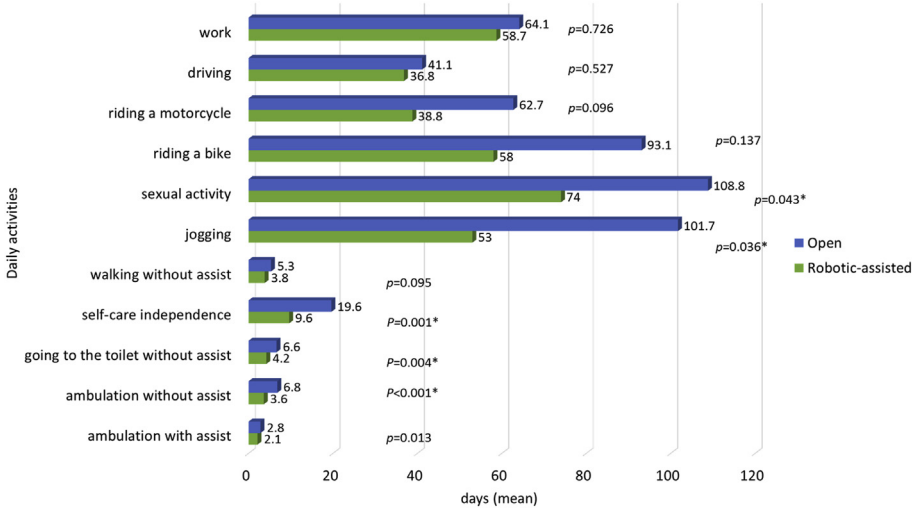


Figure 2 Comparison of time to return to daily activities between the robotic and open groups. Patients underwent robotic hepatectomy reported a shorter period before returning to daily activities compared to open group. Significant differences were documented regarding the time to starting ambulation without assistance, toileting without assistance, self-care independence, jogging, and sexual activity.

Table 4 Comparison of medical Costs of robotic and open hepatectomy.

Medical costs (in US dollars)	Robotic Group (n = 50)	Open Group (n = 50)	*p* value
Peri-operative costs	10951.8	2735.4	<0.001*
Operating room	10299.6	2230.5	<0.001*
Anesthesia	652.2	505.0	0.003*
Inpatient care costs	1546.2	2185.2	0.002*
Room and board	410.7	626.4	<0.001*
Pharmacy	234.8	344.4	0.03*
Laboratory	421.9	511.1	0.01*
Radiology	72.5	133.0	0.13
Other inpatient services	406.2	570.4	0.004*
Total costs	12498.0	4920.6	<0.001*

*Statistically significant, $p < 0.05$.

between the two groups was enhanced with the VAS and long-term wound complaints.

Standardized questionnaire evaluation is more objective for evaluating QoL, and the analysis after scoring will assist in elucidating QoL results of different domains. Although no optimal questionnaire for the evaluation of post-operative QoL regarding hepatectomy was recommended in the literature, the combination of SF-36 and GIQLI has been suggested for QoL evaluation for gastroenteral and gallbladder diseases.[21] Therefore, the well-documented SF-36 together with GIQLI may provide an objective assessment of post-operative QoL after hepatectomy. Our data showed that there was significantly better QoL in the robotic group, including better physical results at post-operative 3 months and 6 months in SF-36, as well as better physical and emotional states at post-operative 6 months, and a better physical state at post-operative 18 months in GIQLI. Moreover, the earlier return of daily activities in the robotic group is consistent with the performance in questionnaires. In this study, robotic hepatectomy provided better QoL in regard to shorter period to ambulation without assistance, toileting without assistance, self-care independence, jogging, and sexual activity.

The expense of applying the robotic platform remains high; however, some suggested that robotic surgery did not increase total costs compared to that of open surgery, while the higher intra-operative costs might be offset by the reduced costs due to shorter hospitalization.[22–24] Consistent with these studies, our data suggested that the inpatient cost of robotic hepatectomy is lower than that of the open approach. However, in Taiwan, the cost of inpatient care is mostly covered by the National Health Insurance, but the payments toward inpatient care were low compared to modern societies; thus, there is a dramatically higher cost of applying the robotic system compared to the other costs of hospitalization. Nevertheless, the longer operation time and expensive cost of robotic surgery are prohibitive factors to many patients who are anatomically suitable for robotic surgery. However, there are an increasing number of patients in our population and worldwide requesting robotic surgeries for the improved wound cosmetics, reduced wound pain, and faster recovery.[25] There is a trend to apply the robotic system for select patients in many procedures, and the benefits of robotic surgery seem to overcome the high costs in some populations. Moreover, our study might underestimate the opportunity benefits of robotic hepatectomy. The shorter hospital stay and faster return to normal daily activities would reduce post-operative costs as well as opportunity costs.

4.1. Limitations

The QoL survey in this study is composed of multi-faceted tools, including an objective PCA dosage and standardized

questionnaires, to minimize the effect of bias between groups. The patient-reported outcomes were inevitably associated with the socioeconomic status of the patients and the answers to the questionnaires could vary considerably as patients of different backgrounds might have a different interpretation of the questions. Therefore, a single qualified interviewer without knowing the operation type used in the cases involving an interview was employed for this study. This could reduce any misunderstanding of the questionnaire and thereby enhance the reliability of the study. Additionally, the survey was performed based on the patients' memory during the out-patient clinic follow-up, and the two questionnaires did not reflect the same statistical significance in consideration of a specific time point. However, the trend of the QoL scoring implied that robotic hepatectomy is capable of providing a good post-operative physical and mental recovery. Our analysis is limited by its retrospective nature. Although all patients who underwent robotic and open hepatectomy were recruited for the analysis, only a limited number of patients completed the survey. This resulted in the smaller tumor size and lower number of malignancy in the robotic hepatectomy group than in the open group. However, no cirrhosis-related complications were observed during the follow-up period.

5. Conclusion

Following our previous reports, this study illustrated that robotic hepatectomy is safe and feasible for select patients.[5,6,20] Although the robotic procedure is associated with decreased cost of inpatient care, the total cost remains high. Adoption the robotic hepatectomy is aimed to provide an alternative treatment resulting in good quality of life and early return to daily activities. Further studies and a more detailed analysis are needed to validate the cost-effectiveness of robotic hepatectomy.

Funding

No funding support was conducted with preparation of this article.

Ethical statement

All authors confirmed that this research was done according to ethical standards.

Conflict of interest

All authors have no conflicts of interest or financial ties to disclose.

References

1. Giulianotti PC, Coratti A, Sbrana F, et al. Robotic liver surgery: results for 70 resections. *Surgery*. 2011;149:29—39.
2. Troisi RI, Patriti A, Montalti R, Casciola L. Robot assistance in liver surgery: a real advantage over a fully laparoscopic approach? Results of a comparative bi-institutional analysis. *Int J Med Robot*. 2013;9:160—166.
3. Wakabayashi G, Cherqui D, Geller DA, et al. Recommendations for laparoscopic liver resection: a report from the second international consensus conference held in Morioka. *Ann Surg*. 2015;261:619—629.
4. Leung U, Fong Y. Robotic liver surgery. *Hepatobiliary Surg Nutr*. 2014;3:288—294.
5. Wu YM, Hu RH, Lai HS, Lee PH. Robotic-assisted minimally invasive liver resection. *Asian J Surg*. 2014;37:53—57.
6. Chen PD, Wu CY, Hu RH, et al. Robotic major hepatectomy: is there a learning curve? *Surgery*. 2017;161:642—649.
7. Salman M, Bell T, Martin J, Bhuva K, Grim R, Ahuja V. Use, cost, complications, and mortality of robotic versus nonrobotic general surgery procedures based on a nationwide database. *Am Surg*. 2013;79:553—560.
8. Sleeper J, Lotan Y. Cost-effectiveness of robotic-assisted laparoscopic procedures in urologic surgery in the USA. *Expert Rev Med Devices*. 2011;8:97—103.
9. Buzad FA, Corne LM, Brown TC, et al. Single-site robotic cholecystectomy: efficiency and cost analysis. *Int J Med Robot*. 2013;9:365—370.
10. Waters JA, Canal DF, Wiebke EA, et al. Robotic distal pancreatectomy: cost effective? *Surgery*. 2010;148:814—823.
11. Herling SF, Moller AM, Palle C, Thomsen T. Health-related quality of life after robotic-assisted laparoscopic hysterectomy for women with endometrial cancer–A prospective cohort study. *Gynecol Oncol*. 2016;140:107—113.
12. Chen PD, Wu CY, Hu RH, et al. Robotic versus open hepatectomy for hepatocellular carcinoma: a matched comparison. *Ann Surg Oncol*. 2017;24:1021—1028.
13. Chen PD, Wu CY, Hu RH, et al. Robotic liver donor right hepatectomy: a pure, minimally invasive approach. *Liver Transplant*. 2016;22:1509—1518.
14. Oken MM, Creech RH, Tormey DC, et al. Toxicity and response criteria of the eastern cooperative Oncology group. *Am J Clin Oncol*. 1982;5:649—655.
15. Belghiti J, Clavien P-A, Gadzijev E, et al. The brisbane 2000 terminology of liver anatomy and resection. *HPB*. 2000;2:333—339.
16. Maruish ME. *User's Manual for the SF-36v2 Health Survey*. 3rd ed. Lincoln, RI: QualityMetric Incorporated; 2011.
17. Ware Jr JE, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care*. 1992;30:473—483.
18. Eypasch E, Williams JI, Wood-Dauphinee S, et al. Gastrointestinal Quality of Life Index: development, validation and application of a new instrument. *Br J Surg*. 1995;82:216—222.
19. Lien HH, Huang CC, Wang PC, et al. Validation assessment of the Chinese (Taiwan) version of the Gastrointestinal Quality of Life Index for patients with symptomatic gallstone disease. *J Laparoendosc Adv Surg Tech*. 2007;17:429—434.
20. Ho CM, Wakabayashi G, Nitta H, Ito N, Hasegawa Y, Takahara T. Systematic review of robotic liver resection. *Surg Endosc*. 2013;27:732—739.
21. Korolija D, Sauerland S, Wood-Dauphinee S, et al. Evaluation of quality of life after laparoscopic surgery: evidence-based guidelines of the European Association for Endoscopic Surgery. *Surg Endosc*. 2004;18:879—897.
22. Morgan JA, Thornton BA, Peacock JC, et al. Does robotic technology make minimally invasive cardiac surgery too expensive? A hospital cost analysis of robotic and conventional techniques. *J Card Surg*. 2005;20:246—251.

23. Sham JG, Richards MK, Seo YD, Pillarisetty VG, Yeung RS, Park JO. Efficacy and cost of robotic hepatectomy: is the robot cost-prohibitive? *J Robot Surg*. 2016 Dec;10(4):307—313.
24. Martin AD, Nunez RN, Castle EP. Robot-assisted radical cystectomy versus open radical cystectomy: a complete cost analysis. *Urology*. 2011;77:621—625.
25. Ocuin LM, Tsung A. Robotic liver resection for malignancy: current status, oncologic outcomes, comparison to laparoscopy, and future applications. *J Surg Oncol*. 2015;112:295—301.