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ORIGINAL ARTICLE

Comparative analysis of learning curve in complex robot-assisted and laparoscopic liver resection

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Abstract

Background: There is no comparative analysis of the learning curves for robot-assisted and laparoscopic liver resection. We aimed to compare learning curves in complex robotic and conventional laparoscopic liver resections with regards to estimation of the difficulty index score.

Methods: The results of 131 consecutive liver resections were analyzed retrospectively (40 robot-assisted and 91 laparoscopic). The learning curve evaluation was based on calculation of procedures number before significant change of the difficulty index for minimally invasive liver resection or the rate of posterosuperior segments resection. Groups of early and late experience were compared in every type of approach (robot-assisted and laparoscopic).

Results: Significant increase of difficulty index (from 5.0 [3.0–7.7] to 7.3 [4.3–10.2]) of robotic procedures required 16 procedures. It was necessary to perform 29 laparoscopic resections in order to significantly increase the rate of laparoscopic posterosuperior segments resection but without significant increase of difficulty index. The implementation of minimally invasive liver resection started with the robotic approach.

Conclusion: The learning curve for robot-assisted liver resections is shorter in comparison with laparoscopic resections. The inclusion of robot-assisted resections in a minimally invasive liver surgery program may be useful to rapidly increase the complexity of laparoscopic liver resections.

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Introduction

During the past quarter of a century since the first laparoscopic liver resection (LLR) was done, laparoscopic technology has become widely used in hepatobiliary surgery. The results of more than 9000 LLR were reviewed in 2015.[1]

The advantages of LLR over open procedures, with regards to short-term results, have been proven by many comparative analyses.[2,3] Survival after LLR is comparable with open resection or even longer in patients with metastatic colorectal cancer and hepatocellular carcinoma.[4–6]

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Nevertheless, it is obvious that the encouraging results of LLR in the majority of series are not without the influence of patient selection, often treated for single lesions located in the anterior segments. As shown in a recent multi-center study, the laparoscopic approach was selected in approximately 30% of all liver resections and in more than 60% of left lateral sectionectomies.[7]

Lesions in the posterior segments of the liver, as well as those with major vascular involvement were not recommended for LLR until recently. Lately published papers indicate that lesions adjacent to major hepatic vasculature do not have to be contraindications to LLR in expert centers.[8] It has been shown that robotic assistance is more effective in parenchymal-sparing liver resection in patients with tumors of posterosuperior liver segments, while the conventional laparoscopic approach usually leads to major liver resection, sacrificing a substantial volume of normal liver.[9,10]

Due to a lack of and controversial results of comparative studies, it remains unclear whether there any advantages to the robotic approach over conventional laparoscopic technologies in difficult-to-reach liver segments resection. To our knowledge, there is still no comparative analysis of learning curves in robot-assisted liver resection (RLR) and LLR, particularly for lesions of difficult-to-reach segments.

Evaluation of the learning curve is typically required for several different measures, reflecting the complexity of the operation or its result. The novel point-based scoring system to assess the difficulty of LLR was recommended in 2014 at the 2nd International Consensus Conference of Laparoscopic Liver Resection.[11] The difficulty scoring system (DSS) was based on an integrated assessment of the complexity of resection, and is useful for standardization of data prior to comparison; however, to date it has not been used for a comparative evaluation of learning curves for minimally invasive liver resection. We aimed to compare learning curves in complex RLR and LLR with regards to estimating short-term results and difficulty index score.

Methods

Study design: observational cohort study. We obtained data on RLR and LLR which were recorded in a prospective database and analyzed retrospectively. All minimally invasive liver resections were performed between May 2010 and June 2016. The first 16 RLR and first 20 LLR were performed at the A.V. Vishnevsky Institute of Surgery with 24 RLR and 71 LLR performed consecutively at the Moscow Clinical Scientific Center. All patients provided informed consent prior to surgery. The primary inclusion criteria were anatomical or partial liver resection for different benign diseases (FNH, hemangioma, adenoma, biliary cystadenoma, liver abscess, intrahepatic cholangiolithiasis), parasitic lesions (hydatid and alveolar echinococcosis) and malignant tumors (colorectal and noncolorectal cancer metastases, hepatocellular carcinoma, intrahepatic and hilar cholangiocarcinoma, gallbladder cancer). Patients with hydatid echinococcosis were included only if total pericystectomy was performed. Patients who underwent minimally invasive unroofing for simple biliary cysts or partial pericystectomy for hydatid echinococcosis were excluded.

A 10-level difficulty index of LLR was calculated as proposed by Ban *et al.*[12] The primary endpoint of this study was to count the number of procedures before a significant increase of difficulty index or the rate of resection of posterosuperior segments as the most powerful category for calculation of difficulty index. Significant changes of difficulty index or the rate of resection of posterosuperior segments were the main conditions for chronological allocation of patients into subgroups of early and late experience for both robotic and laparoscopic approach. The division of RLR and LLR groups into mentioned above subgroups actually reflected the beginning of regular application of minimally invasive technique for complex liver resection with high difficulty index, including posterosuperior segments resection that took place in 2013 for RLR and in 2014 for LLR.

The secondary points were to estimate the duration of liver resection, blood loss, morbidity, mortality and hospital stay. Morbidity was evaluated according to the Clavien–Dindo classification.[13] Grade II–V complications were included in the evaluation. Perioperative mortality was defined as death within 30 days after the procedure or before hospital discharge.

All procedures were performed by two surgeons in equal ratio. At the beginning of the learning curve, operating surgeons had no large experience in laparoscopic surgery but were skilled in open liver surgery, including sophisticated liver resection.

Surgical technique

All LLR and RLR were performed as pure laparoscopic procedures without hand-assistant maneuver. An anti-Trendelenburg position (30°) of the table was used in all cases. For anterolateral segments and segments 1, and 4a resection, patients were placed in the supine position. In segment 7, and 8 resection the right-side-up or left lateral decubitus positions were used. During LLR, the surgeon stood to the right side of the patient. The position of the trocars for anterolateral segments resection was standard for both conventional laparoscopic and robot-assisted approach. As a rule, an optic port was placed through the incision in the umbilical region with surgical (robotic) trocars placed in right and left upper quadrants. By default, assistant trocars were inserted between the optical and surgical ports with one additional trocar placed in the epigastric region near the midline. In the majority of cases, only two robotic arms were used. During conventional laparoscopic procedures, different ports could be used for surgical instrumental handling. We applied the same trocar position for resection of posterosuperior segments, as described by Kazaryan A.M. *et al.* (2011).[14] If necessary, minimally invasive access was converted into an upper midline incision of 8–10 cm in length (the hybrid technique) that was sufficient to complete the procedure. Conversion to a hybrid technique was performed if it was technically challenging to continue the operation safely in a fully laparoscopic variant. The DaVinci S Surgical System (Intuitive Surgical, Inc., Sunnyvale, California) robotic cell was used in the early period, and the DaVinci Si was applied in the late period of the learning curve.

Statistical analysis

Continuous data presented as median values were compared using Mann-Whitney U test. The Two-tailed Fisher's Exact test was used for comparing categorical variables. Spearman correlation coefficient was used to examine the association between series of discrete variables. A p-value of less than 0.05 was considered statistically significant. "Statistica 12" software package was applied for data analysis.

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Results

A total of 131 patients underwent minimally invasive liver resections: 40 RLR and 91 LLR. The early experience groups included 16 RLR and 20 LLR, the groups of late experience consisted of 24 RLR and 71 LLR. Main demographic variables, diagnosis, type of liver surgery, data and parameters influence the complexity of minimally invasive liver resection are showed in Table 1.

The demographic data were similar in the two groups with exception of age as the patients with benign liver diseases who underwent more often RLR were younger than other patients. Colorectal liver metastases were the common indication for surgery for 27% (35/131) of patients underwent minimally invasive liver resection. In a total series of minimally invasive resections benign lesions and malignant tumors as an indication for surgery were distributed almost equally: 52% (68/131) vs 48% (63/131). Among all patients, the rate of hepatectomies for lesions in the posterosuperior segments was 34% (44/131).

As the robotic approach was used initially in implementation of the program of minimally invasive liver surgery, the rate of patients with benign liver diseases in group of RLR was significantly larger than in group of LLR: 62% (25/40) vs 32% (29/91) (p = 0.041). LLR applied more often but not significantly in patients with malignant tumors in comparison with RLR. Laparoscopic technique was used more often than robotic approach for wedge resection of posterosuperior (1, 4a, 7, 8) segments: 25% (23/91) vs 8% (3/40) (p = 0.047) and it was the only approach for right hemihepatectomy: 10% (9/91).

The groups of RLR and LLR were comparable in difficulty index and in three of five parameters, which influence the complexity of minimally invasive liver resection and used for calculation of difficulty index: posterosuperior (1, 4a, 7, 8) segments resection, anatomic resection and cirrhosis. Significant difference between groups of RLR and LLR was found in the rest two parameters: proximity to large vessels (40% [16/40] vs 17% [15/91]; p = 0.027) and tumor size (73 mm [17–142] vs 64 mm [8–180]; p = 0.041) that contributed to difficulty of RLR.

Table 1 Comparison of RLR and LLR on liver lesions, type of liver surgery, demographic data and parameters influence the complexity of minimally invasive liver resection

Diagnosis and procedures	RLR (n = 40)	LLR (n = 91)	p
Benign diseases*	25 (63%)	29 (32%)	**0.041**
Parasitic lesions*	4 (10%)	10 (11%)	0.879
Malignant tumors*	11 (28%)	52 (57%)	0.053
Right hemihepatectomy*	0	9 (10%)	**0.050**
Left hemihepatectomy*	2 (5%)	2 (2%)	0.884
Right posterior sectionectomy*	5 (13%)	6 (7%)	0.307
Segmentectomy 7 ± 8*	1 (3%)	6 (7%)	0.359
Wedge resection of posterosuperior (1,4a,7,8) segments*	3 (8%)	23 (25%)	**0.047**
Anterolateral segment/sectionectomy*	18 (45%)	24 (26%)	0.141
Wedge resection of anterolateral segments*	11 (28%)	21 (23%)	0.674
Age, years (range)**	45 (18–76)	51 (21–77)	**0.029**
ASA score, n (range)**	2 (1–4)	2 (1–3)	0.321
Female/male, n*	31/9	55/36	0.397
Previous laparotomy*	4 (10%)	27 (30%)	0.057
Difficulty index**	6.4 (3.0–10.2)	5.8 (2.5–11.1)	0.123
Posterosuperior (1,4a, 7, 8) segments resection*	11 (28%)	36 (40%)	0.354
Anatomic resection*	29 (72%)	45 (50%)	0.208
Proximity to large vessels*	16 (40%)	15 (17%)	**0.027**
Tumor size (mm)**	73 (17–142)	64 (8–180)	**0.041**
Cirrhosis*	2 (5%)	4 (4%)	0.884

Statistical tests: *Two-tailed Fisher's Exact test; **Mann-Whitney U test; RLR, robotic liver resection; LLR, laparoscopic liver resection; ASA, American Society of Anestesiologists; Significance of bold values indicate p < 0.05.

Surgical outcomes in a whole series of minimally invasive liver resection

The mean blood loss was 358 mL (0–2200); blood transfusion was needed in 5% (7/131) of patients. A significant correlation was found between the difficulty index and amount of blood loss in the entire series of minimally invasive liver resection, which indicates that apart from the experience of the surgeon, the complexity of the resection had a marked influence on the blood loss (Fig. 1a). The mean duration of procedure was estimated at 332 min (70–980). A significant positive correlation was also revealed between the duration of the all procedures and the difficulty index (Fig. 1b).

In whole series conversion was required in 4.5% (6/131) of patients. Although the difficulty index was higher in patients who underwent conversion (7.8 [2.9–11.1]) than in patients with fully laparoscopic procedures (5.9 [2.5–10.0]), there were no significant differences (p = 0.059). Complications were revealed in 18% (23/131) of patients that increased the mean duration of hospital stay to 9 (4–90) days in a whole series.

Surgical outcomes after RLR and LLR

The groups of RLR and LLR were comparable in most of crucial surgical outcomes (Table 2). No significant differences were found between RLR and LLR in blood loss, blood transfusion and conversion rate. The duration of procedure and postoperative hospital stay were longer in RRL group despite of lack of differences in morbidity comparing with LLR group.

The similar surgical outcomes of RLR and LLR present favorable circumstances for comparison of learning curves in both types of minimally invasive liver resection.

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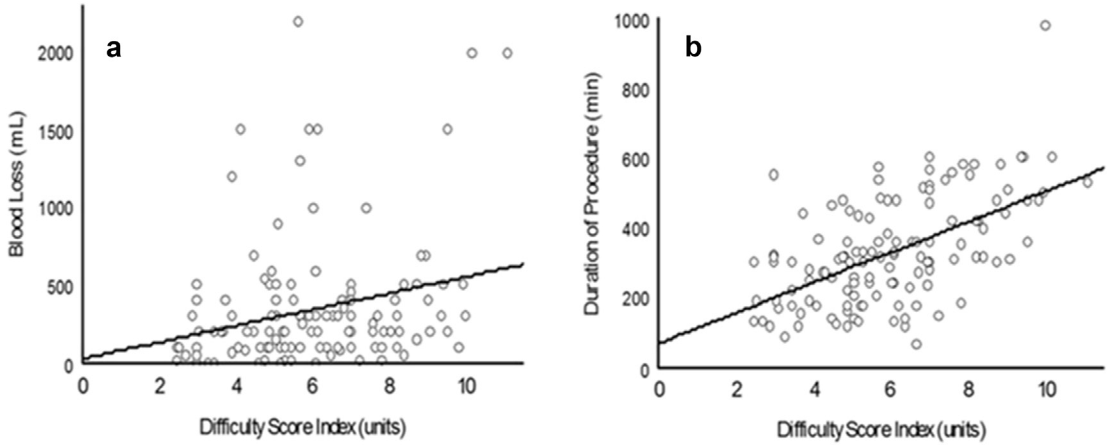

Figure 1 Correlation of difficulty index with blood loss (plot a, Spearman Rank = 0.27, p = 0.003) and duration (plot b, Spearman Rank = 0.53, p < 0.001) in the 131 patients underwent minimally invasive liver resections

Table 2 Surgical outcomes in RLR and LLR groups

Parameters	RLR (n = 40)	LLR (n = 91)	p
Blood loss, mL**	465 (0–2000)	302 (0–2200)	0.181
Blood transfusion*	3 (8%)	4 (4%)	0.492
Duration of procedure (min)**	407 (85–980)	296 (70–605)	**<0.001**
Conversion to hybrid technique*	2 (5%)	4 (4%)	0.884
Morbidity*	8 (20%)	15 (17%)	0.685
Postoperative hospital stay (day)**	11 (6–30)	9 (4–90)	**<0.001**

Statistical tests: *Two-tailed Fisher's Exact test; **Mann-Whitney U test; RLR, robotic liver resection; LLR, laparoscopic liver resection; Significance of bold values indicate p < 0.05.

Surgical outcomes and learning curve evaluation in subgroups of early and late experience

The difficulty index of RLR in the late experience subgroup was significantly higher in comparison with subgroup of early experience: 7.3 (4.3–10.2) vs 5.0 (3.0–7.7) (p < 0.001) due to an increase of all of the factors taken into account in the calculation of difficulty index (Table 3). The rate of posterosuperior segments resection in the late period (46% [11/24]) enlarged significantly comparing with the early period in robotic approach (0%) (p = 0.011) as well as in LLR (53% [33/62] vs 10% [3/29]; p = 0.006). However, the difficulty index did not increase significantly in the late period of LLR. The number of robotic procedures required for a significant increase of difficulty index consisted of 16 (quantity of RLR subgroup of early experience). At the same time, it was necessary to perform 29 LLR in the early period in order to significantly increase the rate of LLR for lesions in posterosuperior segments in the late period. The high rate of anatomic LLR in the early period was achieved at the expense of left lateral sectionectomies (n = 11) and hemihepatectomies (n = 4).

As well as for comparison of entire groups of RLR and LLR no differences were found in majority of surgical outcomes between subgroups of early and late experience for both types of minimally invasive technique despite of significant increase of difficulty and/or the rate of difficult liver resection in the late period (Table 4). The duration of surgery in the late period of the learning curve was longer.

Table 3 Difficulty index and parameters influence the complexity of minimally invasive liver resection in groups of early and late experience

Parameters	RLR early experience (n = 16)	RLR late experience (n = 24)	p	LLR early experience (n = 29)	LLR late experience (n = 62)	p
Difficulty index**	5.0 (3.0–7.7)	7.3 (4.3–10.2)	**<0.001**	5.8 (3.0–9.0)	5.8 (2.5–11.1)	0.927
Posterosuperior (1,4a, 7, 8) segments resection*	0	11 (46%)	**0.011**	3 (10%)	33 (53%)	**0.006**
Anatomic resection*	9 (56%)	20 (83%)	0.444	24 (83%)	21 (34%)	**0.016**
Proximity to large vessels*	4 (25%)	12 (50%)	0.230	2 (7%)	13 (21%)	0.144
Tumor size (mm)**	69 (17–117)	77 (35–142)	0.534	58 (35–90)	68 (8–180)	0.397
Cirrhosis*	0	2 (8%)	0.256	0	4 (7%)	0.176

Statistical tests: *Two-tailed Fisher's Exact test; **Mann-Whitney U test; RLR, robotic liver resection; LLR, laparoscopic liver resection; Significance of bold values indicate p < 0.05.

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More complex liver resections led to initial rise in complication rate, however finally there were no significant differences between groups in morbidity. Severe complications (grade III and above) developed in 9% (12/131) of all patients. Despite slightly higher rate of severe complication after RLR (13% [5/40]) than after LLR (8% [7/91]), there were no differences (p = 0.426). In RLR early period, one patient needed reoperation for bladder injury (discharged on day 8). In the late period of RLR, in four patients bile leakage (grade IIIa) was treated by percutaneous drainage. Biliary complications of grade IIIa after LLR were noticed in one patient in the early period and in three patients in subgroup of late experience. In this subgroup, one patient underwent reoperation for ileus (grade IIIb) and one patient had liver failure (grade IVa) after laparoscopic second stage of ALPPS that was managed without invasive treatment (Grade B, ISGLS). One lethal outcome (0.8% [1/131]) took place in subgroup of late experience of LLR after multiple repeated interventions for severe postoperative pancreatitis with multi-organ dysfunction and consecutive acute thrombosis of the superior mesenteric artery. The patient died of sepsis 90 days after the 1st operation and 75 days after extensive bowel resection.

Discussion

The concept of the learning curve now widely being used in medical science initially was proposed in industrial practice in 1936. The term was defined as an increase in the speed or efficiency of industry product output, while reducing cost and increasing experience and skill of the workforce.[15] According to the just remark of Hopper *et al.*, it is more difficult to find a proper measure of learning related to a surgical technique that could be categorized into measures of surgical process, and measures of patient outcome.[16]

Like in many other fields of surgery, various authors continue to use multiple different and separate factors, the dynamics of which should confirm the improvement of the manual skills of the surgeon in laparoscopic liver resection: operative time, pedicle clamping, number of major liver resection, rate of conversion, blood loss, morbidity, and others.[17–19] Some sophisticated statistical methods (CUSUM) applied for learning curve estimation also refer to surgical events.[19–21]

The outcome of a surgical procedure depends not only upon surgical skill, but also on the complexity of surgery, which in turn is a resultant value of many composing factors. Therefore, it is difficult to compare learning curves for resections of varying complexity, and even more to compare learning curves of different clinics.

In 2014 Ban *et al.* proposed a novel difficulty scoring system (DSS) as a new opportunity for the integral assessment of complexity and risk of laparoscopic liver resection. A 10-level point-based difficulty index reflects the cumulative score for five individual factors: tumor location, tumor size, proximity to major vessels, extent of resection, and preservation of liver function. Finally, procedures spread into three categories of difficulty: low (1–3), intermediate (4–6), and high (7–10).[12] To date, only a few authors have used the DSS for comparative analysis of LLR results.[22] In our series, anatomic parenchyma-sparing resection of posterosuperior segments with vascular involvement proved to be the most complex procedure, according to the DSS.

There is a growing attention to laparoscopic and robotic resections of posterosuperior segments in recent publications. The first papers on the safety and technical tricks of resection for lesions involving posterosuperior segments were published few years ago.[14,23] A few studies have been devoted to the comparative analysis of hepatectomies for lesions in the anterolateral and posterosuperior segments.[14,24,25] Despite the greater complexity and risk of procedures in difficult-to-reach-positions, many authors stress the need for parenchyma-sparing resection.[24,26,27] If parenchyma-sparing resection is unable to be performed by a laparoscopic approach, open surgery is appropriate in order to avoid unreasonable major liver resection, which cannot be justified by minimally invasive approach considerations.[24]

Table 4 Surgical outcomes of RLR and LLR in subgroups of early and late experience

Parameters	RLR early experience (n = 16)	RLR late experience (n = 24)	p	LLR early experience (n = 29)	LLR late experience (n = 62)	p
Blood loss, mL**	518 (20–1500)	411 (20–2000)	0.850	301 (100–700)	303 (20–2200)	0.091
Blood transfusion*	1 (6%)	2 (8%)	0.820	0	4 (7%)	0.176
Duration of procedure (min)**	322 (85–575)	460 (230–980)	**0.005**	243 (70–470)	321 (120–605)	**0.011**
Conversion to hybrid technique*	0	2 (8%)	0.256	0	4 (7%)	0.176
Morbidity*	2 (13%)	6 (25%)	0.424	4 (14%)	11 (18%)	0.687
Postoperative hospital stay (day)**	10 (7–18)	12 (6–30)	0.786	8 (5–12)	9 (4–90)	0.633

Statistical tests: *Two-tailed Fisher's Exact test; **Mann-Whitney U test; RLR, robotic liver resection; LLR, laparoscopic liver resection; Significance of bold values indicate p < 0.05.

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Laparoscopic resection of the posterosuperior segments takes more time and can lead to greater blood loss compared with resection of the anterior segments.[25,28] Resection of the posterosuperior segments, in particular isolated segment 7 resection, are recommended for small tumors (<5 cm) without large vascular involvement, which limits blood loss to approximately 200–600 mL at a conversion rate of up to 0–5%.[13,24] In some series, average blood loss and conversion rate reached 1500 mL and 23%, respectively.[29] In our early experience of partial robotic hepatectomies for lesions in the posterosuperior segments, the blood loss reached 1500–2000 mL; but it required only a few procedures to reduce blood loss.[30]

In a whole series, robotic approach was applied more often than laparoscopic technique for anatomical parenchymal-sparing resection of the posterosuperior segments for lesions with large vessels involvement. Some of laparoscopic procedures were undertaken for lesions extensively involving the inferior vena cava and right hepatic vein. It should be stressed that the implementation of minimally invasive resection of posterosuperior segments started with the robotic approach, which justifies the feasibility of robotic technology application in the early stages of the learning curve.

Well-known technological advantages of the robotic complex, consist of the three-dimensional view offered by the DaVinci robot (Intuitive Surgical, Inc., Sunnyvale, CA), along with the six degrees of freedom afforded by the robotic arms. Nevertheless, the benefits of robotic complex resection of posterosuperior liver segments are not well understood. It has been shown in several papers that parenchymal-sparing resection of the posterosuperior segments was performed more often by a robotic approach in comparison with laparoscopic procedures, which commonly extend to a major resection especially for tumors deeply located in the posterosuperior segments.[9,10,31] In a recent paper, Montalti R. *et al.* (2016) provided evidence for the lack of difference between robot-assisted and laparoscopic resection of posterosuperior segments in a propensity score-matched comparison study.[32]

To our knowledge, there is no published comparative analysis of RLR and LLR results based on difficulty index. The most complex type of LLR is an anatomical parenchymal-sparing resection of the posterosuperior segments which consist of no more than 23.3–25.7% of resections for lesions located in the posterosuperior segments. The remaining cases are treated by major and partial resections.[25,33] Initially, the majority of our patients with lesions in posterosuperior segments underwent anatomical segmental RLR. Later, with experience gained by robotic procedures we extended the indications for LLR of difficult-to-reach segments. Furthermore, extrapolation of robotic experience in liver resections of high difficulty to laparoscopic liver surgery permitted us to rapidly increase the number of LLR (62 within 18 months). The best evidence of comprehension achieved during the robotic learning curve and applied in the laparoscopic field, was an initially low blood loss and low rate of conversion, including laparoscopic resection of difficult-to-reach segments.

In our series, 16 RLR were required to perform resections with a significant increase of difficulty index. Since the analysis includes the total experience of two surgeons who performed approximately the equal number of liver resections the personal experience required to significantly increase the difficulty index of the RLR according to our data is 8–10 procedures. It should be noted that the optimal learning curve in minimally invasive liver resection requires previous sufficient experience in open liver surgery.

More than twice as many LLR as robotic procedures were required for a significant increase in the rate of resections of posterosuperior segments. Therefore, we can assume that the learning curve for RLR, including complex procedures, is shorter than for LLR.

The difficulty index being used for evaluation of the learning curve has its disadvantages. Increase of the difficulty of consecutive procedures is not an unbiased process as it depends in many respects on the surgeon choice, which in turn is dictated by his or her experience, availability of experienced supervision and other circumstances. Therefore the difficulty index cannot be used in some methods based on evaluation of direct outcomes of procedures (CUSUM, etc). Nevertheless, the direct outcomes of the liver resections (blood loss, duration, morbidity, etc) are determined by the level of surgical skill. Therefore, inadequate selection of patients with a high difficulty index must inevitably lead to deterioration in operative results, primarily morbidity. In our study, morbidity and length of hospital stay did not differ significantly between early and late periods. To a certain extent, division of the experience on the early and the late periods was relative but it reflected chronological rapid increase of the number of difficult procedures that was confirmed by significant increase of difficulty index and the rate of posterosuperior segment resections without impairment of surgical outcomes.

Other limitations include retrospective design of our study and non-matched analysis. However, a comparison of learning curves suggests an assessment of nonrandomized retrospective data. Application of the DSS was useful for minimizing the inevitable biases which emerge from a heterogeneity of analyzed series.

Conclusion

One of the options for implementation of minimally invasive liver resection can be the initial use of the robotic approach. It is necessary to perform not less than 8–10 robotic procedures of low and intermediate level of difficulty before proceeding to high difficulty resections. Application of the robotic platform at the beginning of the program of minimally invasive liver surgery can be useful for rapid and safe expansion of indications for complex laparoscopic liver resection.

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Conflicts of interest

Mikhail Efanov, Ruslan Alikhanov, Victor Tsvirkun, Ivan Kazakov, Olga Melekhina, Pavel Kim, Andrey Vankovich, Konstantin Grendal, Stanislav Berelavichus, Igor Khatkov have no conflicts of interest or financial ties to disclose.

All authors have approved the final version of the article.

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