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REVIEW ARTICLE

Analysis of economic impact of laparoscopic liver resection according to surgical difficulty

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Abstract

Introduction The advantages of laparoscopic liver resection (LLR) are well known, but their financial costs are poorly evaluated. The aim of this study was to analyze the economic impact of surgical difficulty on LLR costs, and to identify clinical factors that most affect global charges.

Methods All patients who underwent LLR from 2014 to 2018 in a single French center were included. The IMM classification was used to stratify surgical difficulty, from group I through group III. The costing method was done combining top-down and bottom-up approaches. A multivariate analysis was performed in order to identify clinical factors that most affect global charges.

Results Two hundred seventy patients were included (Group I: $n = 136$ (50%), Group II: $n = 60$ (22%), Group III: $n = 74$ (28%)). Total expenses significantly increased ($p < 0.001$) from Group I to Group III, but there was no difference regarding financial income ($p = 0.133$). Technical platform expenses significantly increased ($p < 0.001$) from Group I to Group III and represented the main expense among all costs with a total of 4 930 ± 2 601€. Among technical platform expenses, the anesthesia platform represented the main expense. In multivariate analysis, the four clinical factors that affected global charges in the whole study population were operating time ($p < 0.001$), length of stay ($p < 0.001$), admission in ICU ($p < 0.001$) and the occurrence of major complication ($p < 0.05$). An admission in ICU was the clinical factor that affected most global charges, as an ICU stay had a 39.1% increase effect on global charges in the whole study population.

Conclusion LLR is a cost-effective procedure. The more complex is the LLR, the higher is the hospital cost. An admission in ICU was the clinical factor that most affected global charges.

Keywords Laparoscopic liver resection · Cost · Surgical difficulty · Postoperative outcomes · Hepatectomy · Complication

Abbreviations

ASA American Society of Anesthesiologists
LLR Laparoscopic liver resection

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Laparoscopic liver resection (LLR) has expanded in the last decades and its feasibility and advantages are widely known and demonstrated [1]. The laparoscopic approach is associated with lower postoperative formation of adhesions, lower parietal damage, a reduction in postoperative pain, morbidity, length of stay and an earlier recovery [2, 3], compared to laparotomy. However, implementation of laparoscopic approach is limited, due to liver anatomy complexity, proximity of large vascular structures, and difficulty in bleeding control [4]. For a safe dissemination of LLR, and to gradually increase skills required in technically demanding procedures. A clear training pathway based on the difficulty of individual procedures within the broad categories of LLR was required. It is believed that this approach will facilitate incremental skill-development and help with safe dissemination of LLR. Several scoring systems have been developed to predict LLR difficulty. In 2017, the Institut

Mutualiste Montsouris (IMM) group reported a three-level classification system designed to stratify the difficulty of 11 different procedures based on intraoperative blood loss, operative time and conversion rate [5].

Even though clinical outcome remains the primary focus, economic evaluations represent an essential part in the assessment of new technologies. They are mandatory for funding decisions, especially in an era where health costs are rising, and government resources are limited. Cost saving obtained through laparoscopic approach could further encourage its implementation. However, health-related costs vary across countries, and medico-economic studies are heterogeneous. Therefore, it is important to identify clinical factors that might influence LLR costs, since relative medico-economic data should be easier to transpose from one country to another.

Hence, the aim of the present study was to analyze the economic impact of surgical difficulty on LLR costs billed to the hospital, and to identify clinical factors that most affect global expenses.

Methods

Study population

From January 2014 to December 2018, all patients who underwent LLR at Institut Mutualiste Montsouris (Paris, France) were identified. Data were retrospectively retrieved from a prospectively maintained database. The data included demographic variables, primary tumor characteristics and management, operative data, tumor pathology, short-term outcomes and economic data. This study was approved by the institutional review board and conducted in accordance with the Declaration of Helsinki.

Surgical procedure

All procedures were performed using standardized surgical techniques; surgical team included two senior HPB surgeons, and techniques were unchanged during the entire study period [6]. The decision for LLR was taken by a multidisciplinary board that included surgeons, medical oncologists, radiologists and pathologists. All resections were performed with curative intent. Intra-abdominal pressure was maintained at 12 mmHg. Laparoscopic ultrasonography was performed routinely to confirm number and size of lesions, and their distance to intrahepatic vascular structures. An intermittent Pringle maneuver was used only in cases of failure of bleeding control. For all procedures, tissue dissection and hemostasis were performed by ultrasonic dissector, mainly the Thunderbeat® (Olympus, Tokyo, Japan) or Harmonic® Scalpel® (Ethicon Endo-Surgery, Cincinnati, Ohio, USA); the Gayet bipolar forceps (MicroFrance CEVBG134; Medtronic, Minneapolis, Minnesota, USA) provided retraction and rescue hemostasis. Conversion was defined as the requirement for laparotomy at any time during the procedure, with the exception of extraction of the resected specimen. Finally, the resected specimen was extracted in a plastic retrieval bag through a suprapubic incision. Drains were used only if there was concern about intraoperative control of biliary tree radicals or adequacy of hemostasis. All intraoperative parameters, including type and duration of vascular clamping, blood loss with subsequent intraoperative blood transfusion and duration of surgery, were recorded.

Surgical difficulty

Major hepatectomy was defined as the resection of three or more contiguous Couinaud segments and minor hepatectomy as the resection of less than three Couinaud segments [7].

LLR were categorized into 3 levels of difficulty (low, intermediate and high) according to the IMM classification [5]. Group I included wedge resection and left lateral sectionectomy. Group II represented the intermediate level with anterolateral segmentectomy (IVb, V, VI, II, III) and left hepatectomy. Group III represented the most technically advanced level including posterosuperior segmentectomy (I, IVa, VII, VIII), right posterior sectionectomy, right hepatectomy, extended right hepatectomy, central hepatectomy, and extended left hepatectomy. When multiple resections of varied difficulty were performed simultaneously, the LLR was classified according to the most difficult procedure. Because the learning curve can have an important impact, we analyzed evolution of expenses over time.

Clinical data and postoperative outcomes

Preoperative data recorded were gender, age, BMI, ASA score, comorbidities, tumor characteristics, type of LLR and group of difficulty.

A fast-track implementation in liver surgery was developed throughout the care pathway: preoperative (informative consultation, reduced preoperative fasting, antibiotic or antithrombotic prophylaxis, no anxiolytic premedication); perioperative (short-acting anesthetic agents, suitable vascular filling, prevention of hypothermia); postoperative (no gastric tube, systematic prevention of nausea and vomiting, early mobilization and refeeding). Post-hepatectomy morbidity and mortality were assessed within 90 days after surgery using Clavien–Dindo [8] classification. Major postoperative complications were defined as Clavien–Dindo > II. Liver failure was defined according to the "50–50" criteria (prothrombin time < 50% and serum bilirubin > 50 µml/L) on postoperative day 5 [9]. Ascites was defined as abdominal drainage output of more than 10 mL per kg per day after the third postoperative day. Biliary leakage was defined by a bilirubin concentration in the drainage fluid more than threefold that in serum, according to the criteria of the International Study Group of Liver Surgery [10]. Medical and surgical complications were distinctively recorded as well as total in-hospital stay. Transfusion of red blood cells was based on clinical assessment, hemodynamic monitoring and concentration of hemoglobin. Above a cut-off of 8.0 g/dL of hemoglobin, transfusion was performed systematically. Patients were admitted in the ICU only in case of major hepatectomy, blood loss > 1000 mL, severe comorbidities or according to unfavorable intraoperative conditions at the discretion of the surgeon and the anesthesiologist.

Economic data

The costing method was done combining top-down and bottom-up approaches. All direct in-hospital expenses borne by the institution were collected. The different expenses were stratified in 5 groups: medical staff, medical expenses, general expenses, technical platform, and ICU stays. The medical staff expenses included medical staff, surgeons, and nonmedical staff (nurses, physiologists, secretaries). The medical expenses included implantable medical devices, drugs, labile blood products, medical devices (surgical instruments, drains, etc.) and medical equipment. General expenses included depreciation charges and other general expenses. Technical platform expenses included operative room (OR), blood banks, pathological analysis, routine or urgent biology, beds management, anesthesia, and perioperative imaging (including postoperative CT-scan if necessary). In French healthcare model, hospitals are funded by activity-based payment. The refund for each patient is based on rates that are determined for each hospital stay, depending on the severity of the underlying pathology and/or complexity of care. The national insurance covers all expenses for the whole population except the extra fees. Interestingly, no extra fees are allowed at our institution. In this study, national healthcare reimbursement represented institution income. Financial income represents the financial products subtracted from the expenses.

Study design

Every patient included was categorized into Group I, II or III, according to LLR surgical difficulty. Clinical and economic data were first compared according to these three groups. Financial weight was then calculated for each group. Finally, a multivariable analysis was performed in order to identify clinical factors that most affect global charges. A specific analysis of financial impact of postoperative complications was performed.

Statistical analysis

Categorial qualitative variables were expressed as number and percentage (%) and were compared using nonparametric χ^2 test. Continuous quantitative variables were expressed as mean (± standard deviation). Since their distributions were not normal, they were compared using nonparametric Kruskal–Wallis test, according to Holm method. Cochran–Armitage and Jonckheere–Terpstra trend tests were used for categorial qualitative and continuous quantitative variables, respectively. In addition, expenses analysis was completed using a nonparametric bootstrap re-sampling technique. The percentile estimation of confidence interval (CI) concluded to a significant difference when CI did not contain 0. Financial weight was then calculated for each group (group expenses/total expenses). A linear regression model was used for multivariate analysis. The financial impact of a clinical factor on global charges was deduced from β coefficient. Statistical significance was accepted at the 0.05 level. All statistical analyses were performed using STATA version 14 (StataCorps, College Station, TX).

Results

Study population

Two hundred and seventy patients were included for analysis. Patients' characteristics, intraoperative and postoperative data are detailed in Table 1. There were 97 (35.9%) women and 173 (64.1%) men. Mean age was 64.9 ± 11.4 years. Regarding surgical procedures, 136 (50%) were in Group I, 60 (22%) were in Group II and 74 (28%) were in Group III. 202 (75%) patients underwent minor hepatectomies, and 68 (25%) underwent major hepatectomies. Minor hepatectomies were mostly atypical resections ($n = 117$, 58%) and major hepatectomies were mostly right hepatectomies ($n = 42$, 62%). The mean blood loss, operating time and transfusion rate were 261 ± 314 mL, 204 ± 93 min and 4.4%, respectively. Mean blood loss and operating time significantly increased from Group I to Group III. Global complications were significantly higher in Group III ($n = 43$, 58.1%) compared to Group I ($n = 29$, 21.3%) and Group II ($n = 17$, 28.3%), ($p < 0.001$). The mean length of stay was 7.9 ± 8.7 days and significantly increased from Group I to III. There was no difference concerning evolution of expenses between the beginning and the end of the study period ($p = 0.892$).

Cost analysis

Detailed expenses items are presented in Table 2. Medical staff expenses were significantly different

Table 1 Demographic characteristics, intraoperative data and postoperative outcomes according to IMM classification

	Total *n* = 270 *n* (%)	Group I *n* = 136 *n* (%)	Group II *n* = 60 *n* (%)	Group III *n* = 74 *n* (%)	*p**
Gender (male/female)	173/97 (64.1/35.9)	87/49 (64.0/36)	35/25 (58.3/41.7)	51/23 (68.9/31.1)	0.446
Age at diagnosis, years, mean ± SD	64.9 ± 11.4	64.0 ± 11.9	67.3 ± 9.2	64.7 ± 11.9	0.079°
Age > 70 years	103 (38.1)	42 (30.9)	30 (50.0)	31 (41.9)	0.030°
ASA Score, mean ± SD	2 ± 0.6	2 ± 0.6	1.9 ± 0.5	2 ± 0.5	–
ASA Score > 2	224 (83.0)	110 (80,9)	50 (83.3)	64 (86.5)	0.585
Diabetes mellitus	32 (11.9)	17 (12.5)	7 (11.7)	8 (10.8)	0.935
Dyslipidemia	47 (17.4)	22 (16.2)	14 (23.3)	11 (14.9)	0.379
Hypertension	86 (31.9)	40 (29.4)	23 (38.3)	23 (31.1)	0.460
Coronary disease	12 (4.4)	3 (2.2)	5 (8.3)	4 (5.4)	0.142
COPD	15 (5.6)	8 (5.9)	2 (3.3)	5 (6.8)	0.672
Tobacco	48 (17.8)	23 (16.9)	9 (15.0)	6 (21.6)	0.567
Alcohol	53 (19.6)	27 (19.9)	13 (21.7)	13 (17.6)	0.835
BMI, mean ± SD	25 ± 4.4	25.1 ± 4.8	25 ± 4.1	24.9 ± 3.8	0.893
BMI > 30	35 (13.0)	19 (14.0)	7 (11.7)	9 (12.2)	0.881
Number of lesions, mean ± SD	2.2 ± 2.6	2.3 ± 2.2	1.5 ± 1.0	2.5 ± 3.7	0.014‡
Lesions size, mm, mean ± SD	33.7 ± 29.0	22.2 ± 17.5	40.3 ± 33.2	46.9 ± 33.0	< 0.001◊
Malignant tumors	256 (94.8)	128 (94.1)	58 (96.7)	70 (94.6)	0.716
Colorectal liver metastasis	214 (79.3)	116 (85.3)	40 (66.7)	58 (78.4)	0.012§
Hepatocellular carcinoma	20 (7.4)	3 (2.2)	10 (16.7)	7 (9.5)	< 0.001§
Cholangiocarcinoma	18 (6.7)	5 (3.7)	8 (13.3)	5 (6.8)	0.044§
Re-hepatectomy	69 (25.6)	30 (22.1)	15 (25.0)	24 (32.4)	0.256
Operating time, min, mean ± SD	203.6 ± 92.9	162.3 ± 77.7	213.1 ± 77.6	273.3 ± 88.3	< 0.001§
Blood loss, mL, mean ± SD	261.2 ± 313.8	134.7 ± 182.6	354.3 ± 405.8	420.8 ± 324.7	< 0.001§
Blood loss > 500 mL	48 (17.8)	7 (5.1)	14 (23.0)	27 (36.5)	< 0.001◊
Transfusion	12 (4.4)	0 (0.0)	6 (10.0)	6 (8.1)	< 0.001§
Unit of packed red blood cells, mean ± SD	0.1 ± 0.6	0	0.3 ± 1.0	0.2 ± 0.6	< 0.002◊
Admission in ICU	36 (13.3)	6 (4.4)	11 (18.3)	19 (25.7)	< 0.001◊
Conversion to open	4 (1.5)	2 (1.5)	0	2 (2.7)	0.438
Global complications	89 (33.0)	29 (21.3)	17 (28.3)	43 (58.1)	< 0.001‡
Mortality	2 (0.7)	1 (0.7)	0 (0.0)	1 (1.4)	0.663
Respiratory failure	13 (4.8)	4 (2.9)	3 (5.0)	6 (8.1)	0.247
Liver failure	7 (2.6)	0 (0.0)	0 (0.0)	7 (9.5)	< 0.001
Ascites	17 (6.3)	0 (0.0)	1 (1.7)	16 (21.6)	< 0.001
Collection	26 (9.6)	5 (3.7)	4 (6.7)	17 (23.0)	< 0.001‡
Biliary fistula	16 (5.9)	1 (0.7)	6 (10.0)	9 (12.2)	< 0.001◊
Clavien I	27 (10.0)	11 (8.1)	7 (11.7)	9 (12.2)	0.571
Clavien II	30 (11.1)	10 (7.4)	4 (6.7)	16 (21.6)	0.003‡
Clavien III	26 (9.6)	7 (5.1)	5 (8.3)	14 (18.9)	0.005†
Clavien IV	4 (1.5)	0 (0.0)	1 (1.7)	3 (4.1)	0.085
Minor complications	57 (21.1)	21 (15.4)	11 (18.3)	25 (33.8)	0.007†
Major complications	32 (11.9)	8 (5.9)	6 (10.0)	18 (24.3)	0.001†
Length of stay, mean ± SD (days)	7.9 ± 8.7	5.7 ± 4.5	9 ± 11.8	11.1 ± 10.4	< 0.001§

SD standard deviation

*p** was calculated using nonparametric χ^2 test for qualitative variables, and nonparametric Kruskal–Wallis test, according to Holm method for quantitative variables. Cochran–Armitage and Jonckheere–Terpstra trend tests were used for categorial qualitative and continuous quantitative variables, respectively

§$p < 0.05$: group I vs II, I vs III et II vs III, ‡$p < 0.05$: group I vs III et II vs III, ◊$p < 0.05$: group I vs II et I vs III, †$p < 0.05$: group I vs III, °$p < 0.05$: group I vs II

Table 2 Costs analysis according to IMM classification

Data in euros (€)	Total $n=270$ mean ± SD	Group I $n=136$ mean ± SD	Group II $n=60$ mean ± SD	Group III $n=74$ mean ± SD	p*
Medical staff	1282 ± 1084	1055 ± 766	1420 ± 959	1595 ± 1517	< 0.001◇
Surgeon	230 ± 203	194 ± 189	243 ± 189	286 ± 227	0.010†
Nonmedical staff	131 ± 114	111 ± 94	143 ± 109	161 ± 143	0.008◇
Total medical staff expenses	1644 ± 1260	1359 ± 945	1805 ± 1 094	2043 ± 1707	< 0.001◇
Implantable medical devices	18 ± 92	10 ± 77	26 ± 70	26 ± 128	0.097
Drugs	66 ± 217	39 ± 100	119 ± 418	75 ± 111	< 0.001◇
Blood products	31 ± 177	0 ± 0	61 ± 294	63 ± 206	0.162
Medical devices	1111 ± 572	1084 ± 612	1 030 ± 446	1229 ± 575	0.005 ‡
Medical equipment	10 ± 11	8 ± 7	12 ± 9	13 ± 15	< 0.001◇
Other medical expenses	72 ± 54	64 ± 50	68 ± 42	89 ± 64	< 0.001‡
Total medical expenses	1 308 ± 702	1205 ± 639	1316 ± 767	1495 ± 728	< 0.001†
Depreciation charge	69 ± 39	58 ± 33	72 ± 40	86 ± 43	< 0.001◇
Other general expenses	14 ± 16	10 ± 8	16 ± 14	20 ± 23	< 0.001◇
Total general expenses	83 ± 48	68 ± 38	88 ± 45	106 ± 58	< 0.001§
Central OR	1084 ± 474	896 ± 347	1120 ± 356	1406 ± 575	< 0.001§
Blood banks	11 ± 59	0 ± 0	12 ± 57	30 ± 98	< 0.001†
Pathology	250 ± 169	232 ± 179	245 ± 135	286 ± 172	0.010†
Laboratory	95 ± 126	54 ± 59	121 ± 202	151 ± 111	< 0.001◇
Beds management	1555 ± 1596	1177 ± 953	1852 ± 2469	2019 ± 1509	< 0.001◇
Anesthesia	1751 ± 764	1729 ± 707	1780 ± 865	1769 ± 791	0.515
Imaging	182 ± 367	91 ± 214	176 ± 440	355 ± 460	< 0.001‡
Technical platform expenses	4 930 ± 2601	4191 ± 1810	5276 ± 3 470	6028 ± 2626	< 0.001◇
ICU stay (days)	780 ± 2721	333 ± 1908	726 ± 2 452	1656 ± 3824	< 0.001‡
Expenses	8745 ± 5310	7157 ± 3431	9211 ± 6063	11,328 ± 6415	< 0.001§
Product	13,638 ± 6047	11680 ± 3695	14,922 ± 7648	16,246 ± 6886	< 0.001◇
Financial income	4893 ± 3967	4524 ± 2978	5711 ± 3547	4918 ± 5548	0.133

SD standard deviation

p* was calculated using nonparametric Kruskal–Wallis test, according to Holm method. In addition, a nonparametric bootstrap re-sampling technique was applied. The percentile estimation of confidence interval (CI) concluded to a significant difference when CI did not contain 0. §CI conclude to a significant difference: group I vs II, I vs III et II vs III, ‡CI conclude to a significant difference: group I vs III et II vs III, ◇CI conclude to a significant difference: group I vs II et I vs III, †CI conclude to a significant difference: group I vs III

($p < 0.001$) between Group I (1359 ± 945€) and Group II (1805 ± 1094€) and between Group I and Group III (2043 ± 1707€). Medical expenses were significantly different ($p < 0.001$) between Group I (1205 ± 639€) and Group III (1495 ± 728 €), while there was no difference between Group II (1316 ± 767€) and the two other groups. The main expense among medical charges was medical devices, especially surgical devices (tissue fusion, mechanical suture staplers and radiofrequency ablation electrodes). General expenses significantly increased ($p < 0.001$) from Group I to Group III (Group I: 68 ± 38€, Group II: 88 ± 45€, Group III: 106 ± 58€). Technical platform expenses were significantly different ($p < 0.001$) between Group I (4191 ± 1810€), Group II (5276 ± 3470€) and Group III (6028 ± 2626€). It represented the main expense among all costs with a total of 4930 ± 2601€. Among technical platform expenses, the anesthesia platform represented the main expense (1751 ± 764€) even though there was no difference between groups. ICU-related expenses were significantly different between Group I (333 ± 1 908€) and Group II (726 ± 2 452€), and between Group I and Group III (1656 ± 3 824€).

Total expenses significantly increased ($p < 0.001$) from Group I to Group III (Group I: 7157 ± 3431€, Group II: 9211 ± 6063€, Group III: 11,328 ± 6415€), but there was no difference between groups regarding financial income ($p = 0.133$).

Financial weights per costs item are detailed in Table 3. Technical platform (59%) and medical staff expenses (19.2%) represented the main expense items, with no

Table 3 Financial weights per total costs items according to IMM classification

Financial weight	Total $n=270$ mean (%) ± SD	Group I $n=136$ mean (%) ± SD	Group II $n=60$ mean (%) ± SD	Group III $n=74$ mean (%) ± SD	p*
Total medical staff expenses	19.2 ± 7.8	19.0 ± 7.8	21.0 ± 7.7	18.2 ± 7.8	0.113
Medical expenses	16.3 ± 6.8	17.6 ± 7.3	15.4 ± 5.2	14.6 ± 6.5	0.011◊
General expenses	1.0 ± 0.4	1.0 ± 0.4	1.0 ± 0.3	1.0 ± 0.4	0.116
Technical platform	59.0 ± 11.0	60.5 ± 9.7	58.5 ± 10.5	56.8 ± 13.3	0.070
ICU stay	4.4 ± 13.4	2.0 ± 10.6	4.0 ± 10.0	9.3 ± 18.6	< 0.001◊

SD standard deviation

p* was calculated using nonparametric Kruskal–Wallis test, according to Holm method, ◊$p < 0.05$: group I vs II an I vs III

difference between groups ($p = 0.070$ and $p = 0.113$, respectively) (Table 4).

Identification of clinical factors affecting global charges

In the multivariable analysis, the four clinical factors that affected global charges in the whole study population were: operating time ($p < 0.001$); length of stay ($p < 0.001$); admission in ICU ($p < 0.001$); and the occurrence of major complication ($p < 0.05$). An admission in ICU was the clinical factor that most affected global charges. An ICU stay had a 39.12% increase effect on global charges in the whole study population (Group I: 53.13%, Group II: 27.92%, Group III: 35.16%). Every additional minute in the OR generated a 0.17% increase of global charges (Group I: 0.17%, Group II: 0.16%, Group III: 0.11%). The occurrence of major complication generated a 13.2% increase of global charges in the whole study population. Each major complication was related to a 11.5% increase in global charges in Group III, but was not identified as an independent significant clinical factor in Group I and II.

Expenses (CI (− 7271; − 4117)), product (CI (− 8729; − 5418)), and financial income (CI (− 2972; − 447)) were significantly different between patients with or without complications. The occurrence of postoperative complications increased global charges (12,400 ± 7274€ vs. 6958 ± 2561€), products (18,367 ± 7867€ vs. 11,326 ± 2846€) and financial incomes (5967 ± 5625€ vs. 4368 ± 2692€).

Discussion

Although it is now established that LLR improves postoperative outcomes and reduces hospital stay [2], cost analysis in Western countries are scarce. With a mean profit of almost 5 000€, the present study confirms that LLR is cost-effective regardless of both surgical difficulty and occurrence of postoperative complications.

As expected, the more complex were the LLR, the higher were the expenses, even though the two main expenses (medical staff and technical platform) were not modified. However, financial income remained comparable between groups, since products increased as well

Table 4 Impact of cost item in global charges, in multivariable analysis

Variables	Total ($N=270$)		Group I ($N=136$)		Group II ($N=60$)		Group III ($N=74$)	
	β coefficient (SD)	Cost impact	β coefficient (SD)	Cost impact	β coefficient (SD)	Cost impact	β coefficient (SD)	Cost impact
Operative time (min)	0.0017 (0.0002)	0.17%***	0.0017 (0.0003)	0.17%***	0.0016 (0.0004)	0.16%***	0.0011 (0.0003)	0.11%***
Length of stay (days)	0.0295 (0.0026)	2.99%***	0.0502 (0.0062)	5.15%***	0.0201 (0.0036)	2.03%***	0.0302 (0.0036)	3.06%***
Admission in ICU	0.3302 (0.044)	39.12%***	0.4261 (0.0951)	53.13%***	0.2462 (0.0819)	21.92%***	0.3013 (0.0521)	35.16%***
Major complication	0.124 (0.049)	13.20%*	0.0181 (0.0985)	1.83%	0.1982 (0.1237)	21.92%	0.1091 (0.0532)	11.53%*
Transfusion	8.3349 (0.0329)	− 0.79%	–	–	0.2375 (0.1076)	26.81%*	− 0.0295 (0.0844)	− 2.90%

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

with surgical difficulty. It is also worth noting that global expenses increase of 10% for every additional hour spent in the OR.

The multivariable analysis identified four clinical factors that most impacted global charges after LLR: operating time, length of stay, major complication and admission in ICU. While operating time is part of the definition of surgical difficulty, the three other factors are related to postoperative outcomes. This suggests that IMM classification was not accurate enough to predict global expenses.

Most published series compared cost-effectiveness of laparoscopic versus open hepatectomy [2, 11, 12], or assessed the financial impact of postoperative complications [3]. None of them considered the complexity of the surgical procedure itself. All series arose from different countries and mostly concerned high volume centers, leading to a wide variation of expenses, due to different professional, economical and cultural norms. However, the expenses observed in our Group III patients were comparable to those reported by Hilal et al. [13], despite a shorter length of stay in their series (5.0 vs. 11.1 days in our series).

Several studies emphasized that bleeding has a major impact on global charges [14]. In the present study, both estimated blood loss and red blood cells transfusion significantly increased with surgical difficulty. Although blood loss is part of the definition of surgical difficulty, it did not have any impact on global expenses after LLR. Surprisingly, transfusion had no financial impact on global charges in the whole cohort. A financial impact was observed exclusively for Group II, with a 26.8% increase of global charges in case of transfusion in this group. This might result from a low transfusion rate (4.4%) in the whole cohort.

The present series confirms that postoperative complications are related to increased expenses. Clavien et al. emphasized that occurrence of postoperative severe complications was the strongest factor of costs. Among patients who developed complications in our series, the occurrence of at least one severe complication resulted in an increase of 13.2% of the total expenses. Surprisingly, financial incomes remain positive because an increase in expenses is mostly compensated by an increase in products.

By engaging both human resources and heavy material resources and facilities, admission in ICU represents the clinical factor that most impacts expenses in our series. This variable has been identified on the multivariable analysis and is therefore independent from occurrence of major complications. This result emphasizes that care of patients with multiple or serious comorbidities, requiring an ICU postoperative management, increases expenses.

Some limitations need to be taken into consideration. First, the study was retrospective, although data were prospectively collected. Secondly, it is a single-center study including a selection of patients explaining why these results may not be reproducible in all institutions, and by all surgeons.

As a conclusion, the more complex is the LLR, the higher are the hospital expenses. Finally, taking refund system in consideration, a complex LLR is not more expensive than an easy LLR. An admission in ICU was the clinical factor that most affected global charges.

Compliance with ethical standards

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