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Utility of a novel scoring system for difficulty of pure laparoscopic hepatectomy for intrahepatic cholangiocarcinoma

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Despite the growing adoption of laparoscopic hepatectomy (LH) for intrahepatic cholangiocarcinoma (ICC), there is no scoring system available designed to evaluate its surgical complexity. This paper aims to introduce a novel difficulty scoring system (DSS), designated as the Wei-DSS, exclusively tailored to assess the surgical difficulty of pure LH for ICC. We retrospectively collected clinical data from ICC patients who underwent pure LH at our institution, spanning from November 2018 to May 2024. Patients were categorized into two levels of Wei-DSS scores (low-difficulty [5–6], and high-difficulty [7–10]) determined by tumor characteristics, liver texture, resection extent and tumor marker levels. A total of 104 patients were enrolled in this study including a low-difficulty (LD) group comprising 47 patients and a high-difficulty (HD) group comprising 57 patients. Perioperative comparisons indicated that the HD group was significantly associated with a longer operation time (318.14 ± 125.89 min vs. 222.83 ± 119.03 min, P < 0.001), higher rates of intraoperative blood transfusions (59.6% vs. 27.7%, P = 0.001), and increased rates of postoperative complications (84.2% vs. 48.9%, P < 0.001) compared to the LD group. The receiver operating characteristic (ROC) curve analysis indicated that the Wei-DSS demonstrated superior predictive accuracy over the Major/Minor Classification for predicting postoperative complication rates (area under the curve [AUC] 0.702 vs. 0.622) and operating time (AUC 0.720 vs. 0.604). The Wei-DSS score may have the potential to assist surgeons in categorizing ICC patients with varying levels of surgical difficulty of LH, though it warrants further validations across multiple centers to solidify its efficacy and reliability.

Keywords Intrahepatic cholangiocarcinoma, Difficulty scoring system, Laparoscopic hepatectomy

Intrahepatic cholangiocarcinoma (ICC), a malignant tumor originating from the intrahepatic bile duct epithelium, presents significant clinical challenges owing to its aggressive behavior and dismal prognosis[1]. Currently, hepatectomy emerges as the primary choice for patients with ICC seeking definitive treatment[2]. Advancements in minimally invasive techniques have facilitated laparoscopic hepatectomy (LH) as an increasingly feasible option[3,4]. Nonetheless, the implementation of LH presents substantial challenges and requires overcoming a steep learning curve, highlighting the importance of continuous practice and the accumulation of expertise[5,6]. Hence, it is crucial to develop valuable surgical difficulty prediction models to aid surgeons in categorizing patients with varying levels of surgical difficulty, ultimately enhancing the quality of patient prognosis.

Traditionally, major hepatectomy has been considered a more challenging surgical type and the Major/Minor Classification has been employed to forecast perioperative and long-term outcomes subsequent to liver resection[7]. Notably, previous studies have demonstrated that the complexity of LH extends beyond the mere extent of resection, intricately interwined with individualized patient factors and tumor characteristics[8,9]. The unique anatomical location of ICC, coupled with its frequent proximity to vital blood vessels and bile ducts, significantly elevates the difficulty of surgical intervention[10]. Despite the increasing use of surgical difficulty scoring system (DSS) for assessing LH[8,9,11,12,], recent literature has primarily focused on hepatocellular

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carcinoma[13], or broadly on laparoscopic liver resection[14], and even robotic liver resection[15]in very recent years. Furthermore, some of the latest literature has even employed machine learning methods to explore surgical difficulty of LH and assess the postoperative complications[16,17].

However, potentially due to the rarity of ICC and the relatively low frequency of LH being performed for this disease, there is currently no DSS specifically designed to evaluate the surgical complexity of pure LH for ICC. This, to some extent, limits the precise formulation of surgical plans, adequate assessment of preoperative preparation, and effective prediction of postoperative outcomes. Therefore, this paper aims to develop a novel DSS for pure LH in the treatment of ICC and compare it with the Major/Minor Classification. To the best of our knowledge, this article is the first to report a novel DSS specifically for assessing pure LH for ICC.

Methods

Patients

This retrospective study meticulously analyzed the records of 104 patients with ICC who underwent pure LH at Zhejiang Provincial People's Hospital between November 2018 and May 2024. The exclusion criteria for this study included: (1) patients who had undergone preoperative antitumor therapy, (2) those with documented extrahepatic metastases, (3) individuals who had undergone recurrent hepatectomy, (4) the presence of concurrent malignant diseases in other organs, (5) cases where mid-operative conversions to open surgery occurred, and (6) lacking of complete clinicopathological data. The study adhered to the principles of the Declaration of Helsinki and gathered data from retrospective data. The study obtained approval from the Institutional Review Board of Zhejiang Provincial People's Hospital. Due to the retrospective nature of the study, the Institutional Review Board of Zhejiang Provincial People's Hospital waived the need of obtaining informed consent.

Clinicopathologic features and perioperative variables

The clinicopathologic features and perioperative variables of the patients were retrieved from the hospital's information system, encompassing gender, age, body mass index, American Society of Anesthesiologists score, physical status, hepatitis B virus infection, the presence of cirrhosis, Child-Pugh classification, International Normalized Ratio, platelet count, serum alanine aminotransferase, aspartate aminotransferase, carcinoembryonic antigen level, carbohydrate antigen 19 − 9 (CA19-9) level, tumor size, tumor number, tumor location, differentiation status, type of hepatectomy, resection margins, lymph node metastasis (LNM), microvascular invasion, operative duration, intraoperative blood loss, utilization of hepatic portal block, intraoperative blood transfusion, length of postoperative stay, morbidity of complications, occurrence of postoperative liver failure (PHLF), bile leakage, pleural effusion, and pneumonia. Major hepatectomy was defined as the surgical resection of three or more liver segments[7]. PHLF was defined in accordance with the criteria established by the International Study Group of Liver Surgery (ISGLS)[18]. Postoperative complications were graded utilizing the Clavien-Dindo classification system[19], with grades I-II considered as minor complications and grades III-IV categorized as major complications.

Difficulty scoring system

A novel DSS was created, designated as the Wei-DSS, taking into account both patient status and tumor characteristics. According to the literature on LH, a tumor size exceeding 5 centimeters may affect surgical difficulty and postoperative complications[8]; tumors located in liver segments (I, IVa, VII, and VIII)[12], closer proximity to major blood vessels[13], and patients with concurrent cirrhosis[20]may all contribute to increased surgical difficulty. Previous studies have concurred that a significant elevation of CA19-9 levels, approximately six-fold or greater, serves as a strong indicator of poor postoperative outcomes[21,22]. Interestingly, our preliminary analysis revealed a significant association between a CA19-9 elevation exceeding six-fold and the prolonged duration of surgery and the incidence of postoperative complications (data not shown). Therefore, the following five factors were included in our scoring system and assigned a score of 2 points each as follows: a tumor diameter exceeding 5 cm, tumor involvement of challenging hepatic segments (I, IVa, VII, VIII), proximity of the tumor to major blood vessels by less than 1 cm, the presence of cirrhosis, and CA 19 − 9 ≥ 222 ug/L (six-fold or greater the normal range) (Table 1). Conversely, 1 point was assigned for each of the aforementioned characteristics that were absent. Based on the cumulative scores, patients were subsequently stratified into two distinct groups: a high-difficulty (HD) group comprising individuals with a final score of 7 points or more, and a low-difficulty (LD) group encompassing those with a score of 6 points or less (Table 1). Notably, the size, location, distance from major blood vessels of the tumor, and whether the patient has cirrhosis are assessed based on preoperative imaging, including ultrasound, computed tomography, and magnetic resonance imaging. The CA19-9 level is

The Wei-DSS parameters	2 Points	1 Point
A tumor diameter exceeding 5 cm	Yes	No
Tumor involvement of challenging hepatic segments including segments I, IVa, VII and VIII	Yes	No
Proximity of the tumor to major blood vessels by less than 1 cm	Yes	No
Prescence of cirrhosis	Yes	No
Carbohydrate antigen 19 − 9 ≥ 222 ug/L (Six-fold or greater the normal range)	Yes	No

Table 1. Parameters and assigned indexes in the Wei-DSS. DSS, difficulty scoring system.

obtained from preoperative tumor marker blood testing. These assessments and the procedures for calculating the Wei-DSS score can be completed preoperatively and are very convenient and practical, typically finished within a few minutes.

Statistical Methods

Categorical variables were presented as frequencies and percentages, with group differences analyzed using either the χ^2 test or Fisher's exact test. For continuous variables, mean ± standard deviation (SD) or median (range) was reported, and statistical significance between groups was assessed using the Mann-Whitney U test. To evaluate the predictive capability of the two classifications, the Receiver Operating Characteristic (ROC) curve was utilized, and the Area Under the Curve (AUC) was compared. All statistical analyses were conducted using R software version 4.3.1, with statistical significance set at $p < 0.05$.

Results

Baseline characteristics based on the Wei-DSS

A cohort of 104 patients diagnosed with ICC underwent pure LH. These patients were divided into two distinct groups based on the Wei-DSS: the LD group comprising 47 patients and the HD group encompassing 57 patients, with a male-to-female ratio of 57:47 across the entire cohort (Table 2). A comparative analysis of baseline and tumor characteristics between the two groups revealed that patients assigned to the HD group exhibited a significantly higher proportion of cirrhosis, poorer physical status, more advanced tumor stages, elevated CA19-9 levels, all indicative of increased surgical complexity ($P < 0.05$ for all comparisons).

Perioperative outcomes based on the Wei-DSS

A comparative analysis of perioperative outcomes between the two groups (Table 3; Fig. 1) demonstrated that patients in the HD group experienced significantly longer operative time (318.14 ± 125.89 min vs. 222.83 ± 119.03 min, $P < 0.001$), a higher frequency of intraoperative blood transfusions (59.6% vs. 27.7%, $P = 0.001$), and extended postoperative hospitalization periods (12 days vs. 8 days, $P = 0.001$), increased rates of LNM (50.9% vs. 17%, $P < 0.001$), higher rates of overall postoperative complications (84.2% vs. 48.9%, $P < 0.001$), Clavien-Dindo I-II complications (70.2% vs. 34%, $P < 0.001$) and occurrence of pleural effusion (59.6% vs. 38.3%, $P = 0.048$).

Baseline characteristics based on the Major/Minor Classification

Patients were categorized into two groups, those undergoing minor hepatectomy and those undergoing major hepatectomy, and the baseline characteristics of each group are summarized in Table 4. The findings indicated that patients who underwent major hepatectomy presented a significantly higher rate of tumors larger than 5 cm (93.3% vs. 23%, $P < 0.001$).

Variable	Low-difficulty group ($N = 47$)	High-difficulty group ($N = 57$)	*P*
Gender, Male	29(61.7)	28(49.1)	0.237
Age > 60 years	40(85.1)	42(73.7)	0.228
BMI> (kg/m^2)[a, b]	23.41 ± 4.03	22.21 ± 3.04	0.175
ASA score > 2	12(25.5)	11(19.3)	0.484
Physical status score ≥ 1	9(19.1)	29(50.9)	0.001
HBV (+)	25(53.2)	34(59.6)	0.508
Cirrhosis	7(14.9)	22(38.6)	0.009
Child-Pugh classification A	47(100.0)	55(96.5)	0.500
AJCC-T stage T1	34(72.3)	29(50.9)	0.029
INR > 1.2	5(10.6)	6(10.5)	> 0.999
PLT ≥ $100*10^9$/L	42(89.4)	53(93.0)	0.762
ALT > 40 IU/L	6(12.8)	12(21.1)	0.307
AST > 40 IU/L	5(10.6)	14(24.6)	0.079
CA19-9 > 222 ug/L	5(10.6)	31(54.4)	<0.001
CEA > 10 ug/L	3(6.4)	8(14.0)	0.346
Maximum tumor size > 5 cm	11(23.4)	34(59.6)	<0.001
Tumors number ≥ 2	4(8.5)	7(12.3)	0.763

Table 2. Baseline characteristics based on the Wei-DSS. Data are expressed as frequencies (percentages), otherwise indicated; The chi-squared (χ^2) test or Fisher's exact test is used to compare these data differences between the groups. BMI, body mass index; ASA, American Society of Anesthesiologists; HBV, hepatitis B virus; INR, international normalized ratio; PLT, platelets; ALT, alanine aminotransferase; AST, aspartate aminotransferase; CEA, carcinoembryonic antigen; CA19-9, carbohydrate antigen 19 − 9. a. Data are expressed as mean ± standard deviation. b. The Mann-Whitney U test is used to compare the differences in these data between the groups.

Variable	Low-difficulty group ($N=47$)	High-difficulty group ($N=57$)	P
Operative time (min)[a, b]	222.83 ± 119.03	318.14 ± 125.89	<0.001
Intraoperative blood loss (ml)[a, b]	320.85 ± 420.40	358.77 ± 344.23	0.191
Intraoperative blood transfusion	13(27.7)	34(59.6)	0.001
Utilization of hepatic portal block	17(36.2)	16(28.1)	0.404
Length of postoperative stay (days)[b, c]	8(3–20)	12(3–41)	0.044
Morbidity of complications	23(48.9)	48(84.2)	<0.001
Clavien-Dindo I-II complication	16(34.0)	40(70.2)	<0.001
Clavien-Dindo III-IV complication	7(14.9)	8(14.0)	> 0.999
PHLF	2(4.3)	6(10.5)	0.289
Bile leakage	4(8.5)	11(19.3)	0.163
Pleural effusion	18(38.3)	34(59.6)	0.048
Pneumonia	7(14.9)	14(24.6)	0.326
R0 resection	45(95.7)	55(96.5)	> 0.999
Lymph node metastasis	8(17.0)	29(50.9)	<0.001
Tumor differentiation, moderate/poor	44(93.6)	57(100.0)	0.178

Table 3. Perioperative outcomes based on the Wei-DSS. Data are expressed as frequencies (percentages), otherwise indicated; The chi-squared (χ^2) test or Fisher's exact test is used to compare these data differences between groups. PHLF, postoperative liver failure. a. Data are expressed as mean ± standard deviation. b. The Mann-Whitney U test is used to compare the differences in these data between groups. c. Data are expressed as median (range).

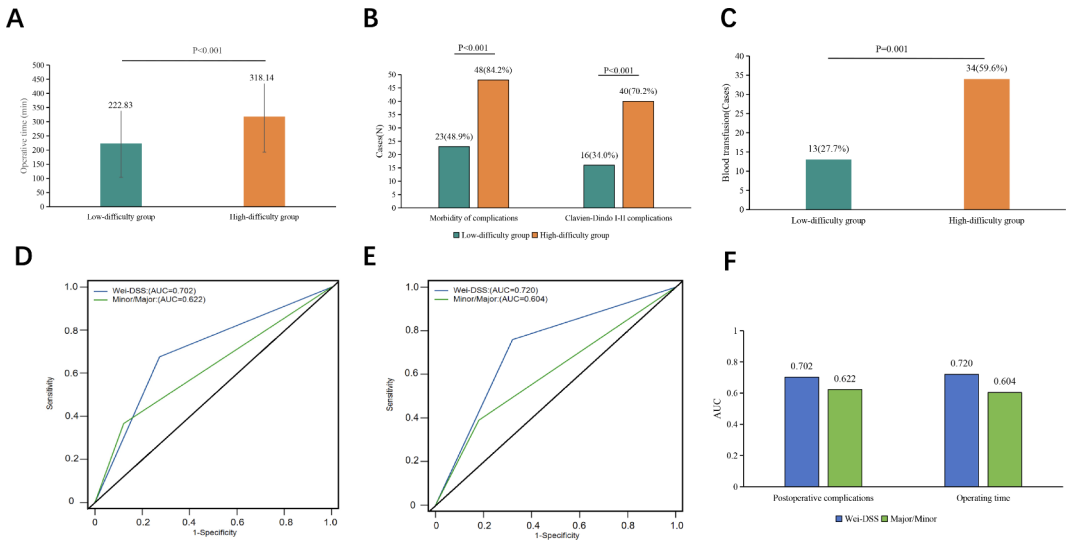

Fig. 1. Comparison of operating time (**A**), morbidity of complications (**B**), blood transfusions (**C**) between the low-difficulty and high-difficulty groups, and comparison of predictive ability of Wei-DSS and the Major/Minor Classification for postoperative complications (**D**, F) and operating time (**E**, **F**).

Perioperative outcomes based on the Major/Minor Classification

A comparative analysis of perioperative outcomes between the two groups (Table 5) indicated that patients in the major hepatectomy group experienced higher rates of overall postoperative complications (86.7% vs. 60.8%, $P=0.011$), Clavien-Dindo I-II complications (76.7% vs. 44.6%, $P=0.004$) and increased rates of LNM (66.7% vs. 23%, $P<0.001$).

Comparing the predictive efficacy of two classification systems

Both the Wei-DSS and the Major/Minor Classification successfully distinguished surgical difficulty, as evidenced by significant differences in operative time ($P<0.001$ and $P=0.055$, respectively), postoperative complication rates ($P<0.001$ and $P=0.011$, respectively) and LNM rates ($P<0.001$ and $P<0.001$, respectively). Furthermore, the Wei-DSS proved to be a more comprehensive predictor than the Major/Minor Classification, encompassing also the likelihood of intraoperative blood transfusion ($P=0.001$ vs. $P>0.005$, respectively) and postoperative hospitalization duration ($P=0.044$ vs. $P>0.05$, respectively). An ROC curve analysis indicated that the Wei-DSS

Variable	Minor($N=74$)	Major($N=30$)	*P*
Gender, Male	44(59.5)	13(43.3)	0.192
Age > 60 years	60(81.1)	22(73.3)	0.431
BMI> (kg/m^2)[a, b]	22.78 ± 3.71	22.67 ± 3.02	0.931
ASA score > 2	15(20.3)	8(26.7)	0.602
Physical status score ≥ 1	25(33.8)	13(43.3)	0.377
HBV (+)	44(59.5)	15(50.0)	0.392
Cirrhosis	17(23.0)	12(40.0)	0.094
Child-Pugh classification A	73(98.6)	29(96.7)	0.496
AJCC-T stage T1	49(66.2)	14(46.7)	0.079
INR > 1.2	9(12.2)	2(6.7)	0.636
PLT ≥ $100*10^9$/L	66(89.2)	29(96.7)	0.399
ALT > 40 IU/L	15(20.3)	3(10.0)	0.263
AST > 40 IU/L	14(18.9)	5(16.7)	> 0.999
CA19-9 > 222 ug/L	22(29.7)	14(46.7)	0.115
CEA > 10 ug/L	6(8.1)	5(16.7)	0.350
Maximum tumor size > 5 cm	17(23)	28(93.3)	<0.001
Tumors number ≥ 2	9(12.2)	2(6.7)	0.636

Table 4. Baseline characteristics based on the Major/Minor Classification. Data are expressed as frequencies (percentages), otherwise indicated; The chi-squared (χ^2) test or Fisher's exact test is used to compare these data differences between the groups. BMI, body mass index; ASA, American Society of Anesthesiologists; HBV, hepatitis B virus; INR, international normalized ratio; PLT, platelets; ALT, alanine aminotransferase; AST, aspartate aminotransferase; CEA, carcinoembryonic antigen; CA19-9, carbohydrate antigen 19 − 9. a. Data are expressed as mean ± standard deviation. b. The Mann-Whitney U test is used to compare the differences in these data between the groups.

Variable	Minor($N=74$)	Major($N=30$)	*P*
Operative time (min)[a, b]	258.49 ± 123.95	315.97 ± 141.58	0.055
Intraoperative blood loss (ml)[a, b]	336.22 ± 374.23	355.00 ± 397.05	0.959
Intraoperative blood transfusion	29(39.2)	18(60.0)	0.081
Utilization of hepatic portal block	24(32.4)	9(30.0)	0.822
Length of postoperative stay (days)[b, c]	8(3–41)	9(5–30)	0.445
Morbidity of complications	45(60.8)	26(86.7)	0.011
Clavien-Dindo I-II complication	33(44.6)	23(76.7)	0.004
Clavien-Dindo III-IV complication	12(16.2)	3(10.0)	0.610
PHLF	4(5.4)	4(13.3)	0.333
Bile leakage	9(12.2)	6(20.0)	0.470
Pleural effusion	36(48.6)	16(53.3)	0.829
Pneumonia	13(17.6)	8(26.7)	0.419
R0 resection	71(95.9)	29(96.7)	> 0.999
Lymph node metastasis	17(23.0)	20(66.7)	<0.001
Tumor differentiation, moderate/poor	71(95.9)	30(100.0)	0.555

Table 5. Perioperative outcomes based on the Major/Minor Classification. Data are expressed as frequencies (percentages), otherwise indicated; The chi-squared (χ^2) test or Fisher's exact test is used to compare these data differences between groups. PHLF, postoperative liver failure. a. Data are expressed as mean ± standard deviation. b. The Mann-Whitney U test is used to compare the differences in these data between groups. c. Data are expressed as median (range).

demonstrated superior predictive accuracy over the Major/Minor Classification for predicting postoperative complication rates (AUC 0.702 vs. 0.622) and operating time (AUC 0.720 vs. 0.604).(Fig. 1).

Discussion

As a minimally invasive surgical approach, LH has gained widespread adoption in the management of ICC over recent years[3,4,23]. Compared to traditional open surgery, LH offers significant advantages, including reduced intraoperative bleeding, enhanced R0 resection rates, and a lower prevalence of postoperative complications,

making it an increasingly preferred treatment option[3,4,23]. Nonetheless, performing LH poses a greater challenge and requires overcoming a steep learning curve[6]. When confronted with LH for ICC varying in surgical difficulty, surgeons must engage in more rigorous pre-operative planning, meticulously considering factors such as the extent and method of resection, the necessity of lymph node dissection, and more, in order to comprehensively ensure the safety and efficacy of the surgical procedure. Therefore, it is crucial to thoroughly assess the complexity of LH for ICC before initiating surgical interventions, to ensure a more informed and customized treatment plan.

Our study included a cohort of 104 patients, who were categorized into two groups according to the Wei-DSS. The baseline data analysis revealed a significant correlation between increased surgical difficulty and more progressed tumors. The comparison revealed a notable correlation between the HD group and a significantly elevated incidence of postoperative complications ($P< 0.001$), which is consistent with previous reports which have also noted that more complex LH procedures may elevate the risk of postoperative complications[9,24].

Conventionally, surgical difficulty has always been categorized based on the distinction utilizing the Major/Minor Classification, though the limitations of this approach are becoming increasingly evident[7]. Notably, the caudate lobe poses a greater surgical challenge compared to the left lateral segment, primarily due to its deeper anatomical location and intricate blood supply network[25,26]. Furthermore, the right liver exhibits elevated hepatic venous pressure, which is linked to a heightened risk of inferior vena cava or right adrenal hemorrhage in comparison to the left liver. Consequently, right hepatic resection often entails longer operative durations and higher blood loss[11]. Hence, the surgical complexity of LH transcends the mere number of resected liver segments and involves a multitude of other factors, include tumors involving particularly challenging liver segments, their close proximity to major blood vessels, as well as the specific texture of the liver tissue, all of which may contribute to the overall complexity of the surgical procedure.

Our study revealed that the traditional categorization of the Major/Minor Classification did not yield significant distinctions in operative duration ($P> 0.05$), thereby demonstrating its limited efficacy in accurately differentiating between varying degrees of surgical difficulty of LH for ICC. Interestingly, previous studies have documented that major hepatectomy is associated with prolonged operative times, highlighting its inherently challenging nature[27]. However, the ROC curve analysis in the current study demonstrated that the Wei-DSS, with AUC values of 0.720 and 0.702, respectively, possessed a superior capability to predict both operating time and the postoperative complication rate over the Major/Minor Classification. This finding indicates that the Wei-DSS possesses the capacity to predict the surgical difficulty of LH for ICC.

Notably, cirrhosis is included as one of the factors in the Wei-DSS, emphasizing its potential importance in surgical difficulty assessment and decision-making[28]. Factors such as the hardness of the liver parenchyma and compromised liver regeneration capacities contribute to the potential difficulties encountered during hepatic resection in patients with cirrhosis[29]. In cirrhotic patients, the impact of surgical trauma on vital liver functions may increase the risk of postoperative decompensation, manifesting as aggravated jaundice, persistent ascites, and the onset of hepatic encephalopathy[30]. Nonetheless, the impact of cirrhosis on post-surgical prognosis remains a subject of ongoing debate and controversy[31,32]. In the context of LH for ICC, it is crucial to acknowledge that the presence of cirrhosis may not only increase the complexity of surgical procedures but may also exert a significant influence on clinical outcomes.

CA19-9 serves as a readily available blood biomarker, widely utilized for both diagnosing and prognosticating ICC[21]. Previous research has consistently reported a significant correlation between preoperative serum CA19-9 levels and the tumor stage of ICC[33]. Furthermore, heightened serum CA19-9 levels have been linked to an elevated risk of early recurrence and poorer prognosis following radical resection for ICC[34]. Previous studies have also indicated that a significant elevation of CA19-9 levels, approximately six-fold or greater, correlates with poor postoperative outcomes[21,22]. Consequently, we incorporated this threshold of CA19-9 elevation into our Wei-DSS model, which has shown a satisfactory ability to forecast the surgical difficulty of LH for ICC. This suggests that when assessing surgical difficulty, we must go beyond mere consideration of tumor size and location, to also factor in test indicators, which may significantly inform our decision-making.

Given the distinct anatomical positioning and oncologic characteristics of ICC, LH poses more intricate challenges compared to other liver diseases. To address this, we have developed a tailored novel Wei-DSS designed for pure LH in ICC cases. This scoring system categorizes patients into LD and HD groups, thereby serving as a valuable tool to navigate surgeons through the learning curve. Scholars have demonstrated that completing 60 minor LHs prior to embarking on major LHs conferred sufficient experience for proficient performance[35]. Similarly, others determined that the median time curve for mastering LH spanned across 50 cases[36]. Intriguingly, future endeavors could explore the potential of assessing surgeons' learning curves through analyzing their surgical portfolio, specifically the ratio of HD/LD cases completed. This approach may hold significant promise and is eagerly anticipated for its insights into surgeon proficiency.

Moreover, LNM is considered a pivotal adverse prognostic indicator in ICC patients[37], yet there remains a persistent debate surrounding the necessity of routine lymph node dissection[38,39]. Current literature has consistently corroborated the widespread adoption of lymph node dissection especially among patients with positive lymph nodes[40]. Notably, for those patients with negative lymph nodes, some scholar suggests that lymph node dissection does not confer a discernible survival advantage[41]. Furthermore, excessive or unnecessary lymph node dissection may potentially lead to bile leakage and liver injury, thereby increasing the risk of postoperative complications[42]. Our study revealed a statistically significant correlation between increased surgical difficulty and a higher incidence of LNM ($P< 0.001$) both based on the Wei-DSS and the Major/Minor Classification. It is plausible that a more extensive lymph node dissection may add to the complexity of the operation; Within the context of higher surgical difficulty, it is paramount to accord greater attention to lymph node dissection, ensuring a comprehensive and meticulous execution that aids in accurate staging and potentially enhances patient outcomes.

In recent years, machine learning has shown considerable potential in predicting outcomes following LH[16,17,43]. By analyzing multidimensional data, machine learning algorithms can detect intricate patterns that are challenging to discern using traditional statistical methods[44], thereby offering enhanced prediction accuracy. Furthermore, algorithms such as deep learning and Light Gradient Boosting Machine demonstrate remarkable proficiency in managing patients with complex conditions, as they seamlessly adapt to a wide range of variable and intricate predictive variables[45,46]. Due to the relatively small number of ICC cases available, the current study did not incorporate machine learning analyses. However, as data accumulates, hybrid models that integrate traditional scoring systems with machine learning techniques are anticipated to emerge in the future.

While this study offers valuable insights, it is important to acknowledge its limitations. First, being a single-center retrospective study, it inherently carries the risk of patient selection bias, which may influence the outcomes. Furthermore, it is noteworthy that our model has not yet to undergo external validation, which could potentially influence its broader applicability and generalization. To build upon and strengthen our findings, future research endeavors will necessarily incorporate prospective, multicenter studies featuring larger sample sizes.

Conclusion

The Wei-DSS score may have the potential to assist surgeons in categorizing ICC patients with varying levels of surgical difficulty of LH, though it warrants further validations across multiple centers to solidify its efficacy and reliability. Incorporating machine learning methods in the future may further enhance predictive capabilities for surgical difficulty and postoperative complications, thereby providing more personalized treatment decision support and ultimately improving patient prognosis.

Data availability

The data gathered in the current study are available from the corresponding author on reasonable request.

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Author contributions

Wei FQ, Du CF, Cao WL reviewed related articles and developed the study; Wei FQ, Du CF, Cao WL wrote the article; Wei FQ, Du CF, Cao WL, Liu JW, Liu J, Jin LM and Feng X and Zhang CW collected data, completed follow up and performed data analysis; Wei FQ edited the article.

Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate statement

The study adhered to the principles of the Declaration of Helsinki and gathered data from retrospective data. The study obtained approval from the Institutional Review Board of Zhejiang Provincial People's Hospital. Due to the retrospective nature of the study, the Institutional Review Board of Zhejiang Provincial People's Hospital waived the need of obtaining informed consent.

Additional information

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